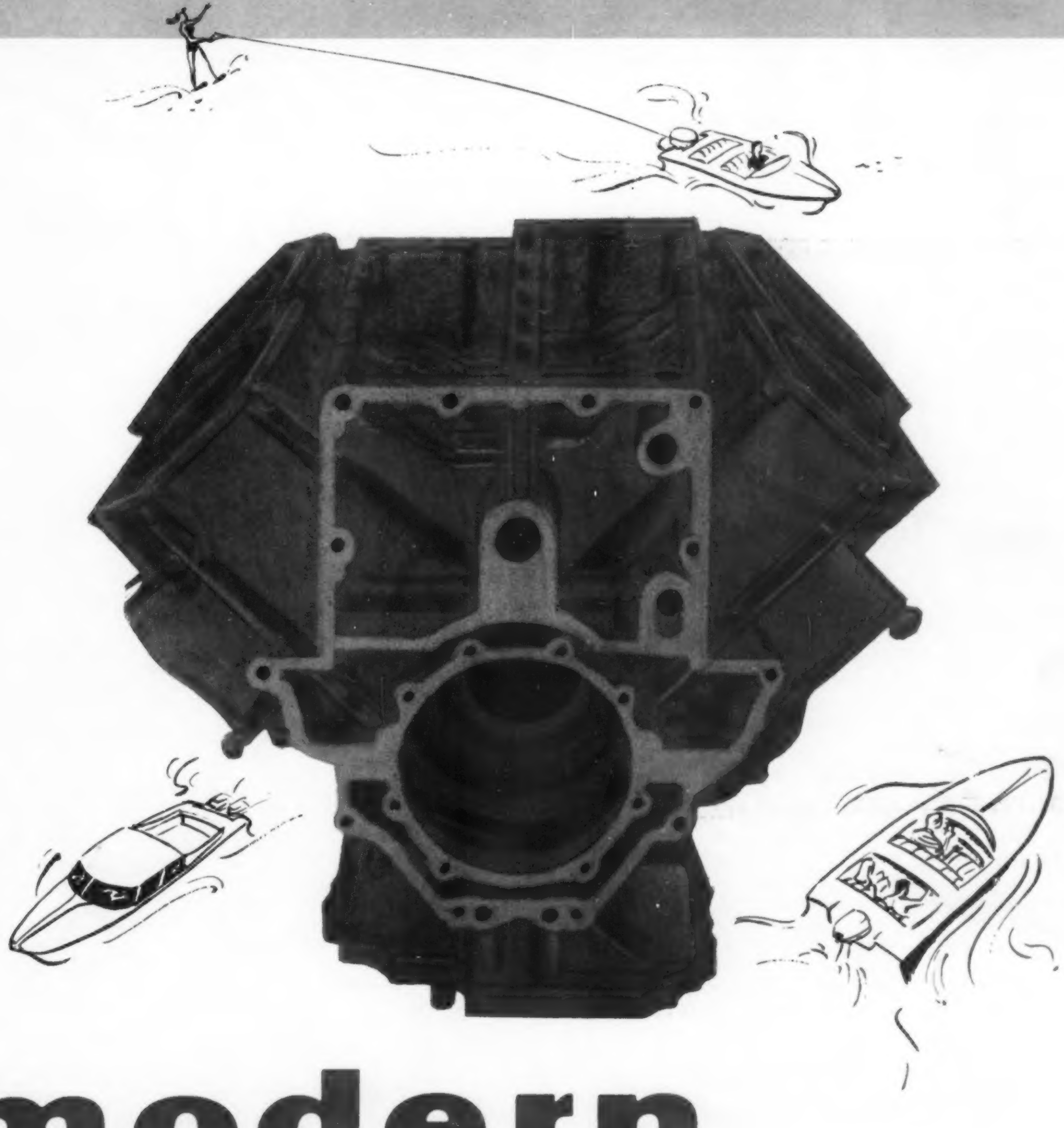
New Market Opportunities for Gray Iron p. 27

How to Make Money in the Foundry Business p. 40

Lifesaver for Bottom Boards p. 36

What Sulzer Put in Its New Foundry p. 30



modern castings

JULY 1960

Be sure of your melts with high-purity Inco Nickel

You can control the properties your customers want, by adding the right Nickel Foundry Products to your ferrous or non-ferrous castings. Nickel promotes resistance to heat and corrosion ... boosts low-temperature impact strength, fatigue resistance ... increases machinability and heat treatability. And Nickel can add practical combinations of these and other properties, economically.

Product purity plus a wide selection of commercial alloying forms makes it easy for you to satisfy customers ... and speed production. Whatever your methods or equipment, you can choose the most convenient forms from the full Inco line, including...

Nickel for general alloying

High-purity electrolytic Nickel Squares – one of the purest and most economical commercial forms. For charging into most common furnaces...electric, cupola or open hearth. In sizes to fit your needs: full-size or cut cathodes ... standard squares from 9 x 9 x 3/8 to 1 x 1 x 3/8 inches ... and "QM" Quick-Melting 1 x 1 x 1/8 inch squares for non-ferrous alloying.

High-purity "XX" Nickel Shot – for alloying with steel or iron at the ladle or spout. Improves toughness, resistance to impact (particularly at low temperature), corrosion resistance, heat treatability, fatigue resistance and many more. Standard sized shot packed in 475 lb. drum.

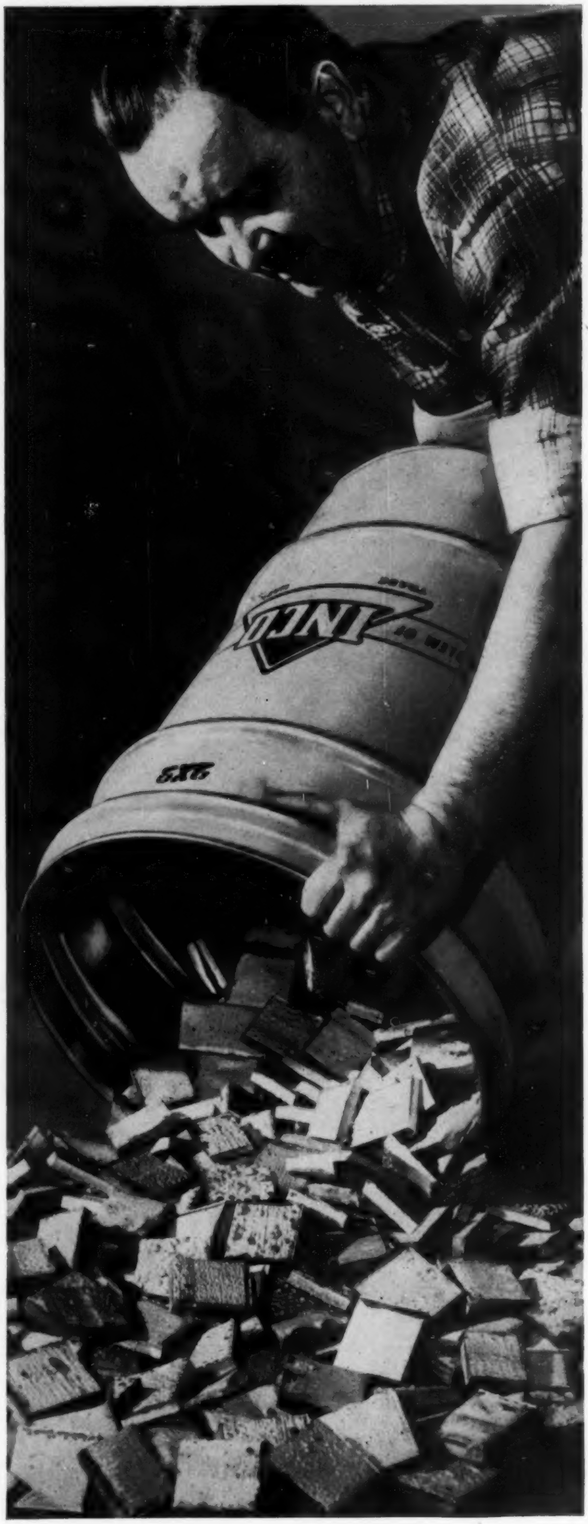
Nickel alloys for iron melts

"F"* Nickel Shot and Ingot – melts at 2300°F for quick solution in molten gray irons. Promotes fine and uniform graphite distribution. Improves machinability, wear-resistance, shock-resistance – especially important in thick-to-thin section castings. Shot is sized for easy addition at ladle or spout.

Nickel-Magnesium Additives NMA#1* and NMSA#2* – for desired properties in both regular and austenitic ductile irons. NMA#1 provides highest magnesium recovery of all commercial additives. NMSA#2 improves toughness and ductility. Both additives promote ease of heat treatment and may be used with all types of ladle treatment methods.

For immediate delivery and further product information, call your local Inco Foundry Products distributor. For information on how Nickel can improve the properties of iron, steel and non-ferrous castings, write Inco directly. Ask for the useful booklet, "A Quick Guide to the Nickel-Containing Casting Alloys."

*Registered trademark



THE INTERNATIONAL NICKEL COMPANY, INC.

67 Wall Street — New York 5, N. Y.

INCO NICKEL

NICKEL MAKES CASTINGS PERFORM BETTER LONGER

Another CARVER "COMPATIBLE CO_2" First!

THE NEW CARVER CARV-O-MATIC* MOLD STATION

*Patent Applied For

50% more Production with this new, fully-automatic, one-man mold station!

Now—"Push Button" Core-making that Saves TIME (50% more molds per hour); LABOR (one-man operation); SPACE (less than 57 sq. ft.); and MONEY (far less rejects — thanks to completely automatic handling).

The new CARVER "CARV-O-MATIC" Mold Station is a revelation in core and mold-making-efficiency.

Based upon a continuous rotation principle, each complete cycle automatically shoots, gasses, and ejects four flasks — delivering the molds or cores directly to the conveyor.

The operator is not required to move a single step from his position at the control panel to achieve continuous sand-to-finished core production.

With complete automation, the incident of human error has been virtually eliminated and rejects can be attributed only to faulty mixtures or improperly made or vented flasks. Mail coupon for complete details.

Carver FOUNDRY PRODUCTS CO.
MUSCATINE, IOWA

Everything for the CO_2 Process

CARVER FOUNDRY PRODUCTS CO.
Muscatine, Iowa
Please send complete information on new CARV-O-MATIC MOLD STATION.

FOUNDRY ______

ADDRESS ______

CITY ______ STATE ______

NAME ______

Circle No. 122, Page 139

July 1960 Vol. 38, No. 1

modern castings

world-wide technical authority of the metalcasting industry

COVER

Drawn by Charles Roth. See page 136 for story about this month's cover: The Largest Commercial Die Casting.

MANAGEMENT

15 Ways Your Gray Iron Business Can Grow 27
"New Alertness Needed Today" .... Jack H. Schaum 28
How to Make Money in the Foundry Business .... Roger B. Sinclair 40

FOUNDRY TECHNIQUES

What Sulzer Put in Its New Foundry .... F. Eisermann 30
Magnified 12,500 Times! .... Donald A. Pearson 38
Lifesaver for Bottom Boards .... George H. Seaberg 36
Casting Defects . . . Part IV of a series on Green Sand Principles for Controlling Quality, . . . R. W. Heine, E. H. King, and J. S. Schumacher 46

CASTINGS CONGRESS PAPERS

Technical Highlights .... S. C. Massari 50
Factors Contributing to Soundness of Titanium Castings .... J. W. Smith and T. A. Hamm 51
High-Strength Cast Steel Structure and Microporosity Effect on Mechanical Properties .... S. Z. Uram, M. C. Flemings, and H. F. Taylor 61
Dust Collector Review .... D. G. Stephan 75
Oxygen-Gas Burner for Scrap Meltdown in the Small Arc Furnace .... V. J. Howard 84
Gap Formation in Permanent Mold Castings .... J. G. Henzel, Jr. and J. Keverian 87
Cast Iron Heat Treatment .... P. H. Diran, Jr. 94
Phenolic Resin Bond in Solid Sand Cores .... H. K. Salzberg and J. J. Greaves 101
Aluminum Alloy with High Silicon Content .... E. E. Stonebrook 111

NEWS OF THE INDUSTRY

Around the World 7
National News 117
AFS Chapter News 120
Foundry Trade News 127
How's Business? 134

OPINION MAKERS AND OPINIONS

Buying Power—and AFS "Influentials" .... H. E. Green 5
Reader Opinions and Ideas 10
Summer, Sweat & Scotch .... H. J. Weber 19
The Grapevine .... H. F. Dietrich 20
Teaching or Telling? .... R. E. Betterley 23
The Editor Reports .... J. H. Schaum 144

SERVICES

Chapter Meetings 126
Products & Processes 128
National Meetings 130
New Books for You 130
Personalities 131
Obituaries 132
Advertising Index 136
For the Asking 138
Classified Advertising 142

AUGUST ISSUE

Don't Murder Your Foundry Business .... I. Elbaum
Gray Iron Metallurgy for Machinability .... Morris Gittleman
Stacker Cranes .... A New Concept in Materials Handling

Modern Castings is indexed by Engineering Index, Inc., 29 West 39th St., New York 18, N. Y. and microfilmed by University Microfilms, 313 N. First St., Ann Arbor, Mich.
The American Foundrymen's Society is not responsible for statements or opinions advanced by authors of papers or articles printed in its publication.
Published monthly by the American Foundrymen's Society, Inc., Golf & Wolf Roads, Des Plaines, Ill. Subscription price in the U.S., $5.00 per year; elsewhere, $7.50. Single copies 50c. April, May and June issues $1.00. Entered as second-class mail at Pontiac, Ill. Additional entry at Des Plaines, Ill.

coke . . . carefully hand-picked . . .
to give you better melting in your cupola

Every foundryman knows how important *uniform coke size* is to a successful melting operation. Size bears a close relationship to carbon absorption, temperature rise, rate of combustion or reactivity, and to pressures.

That's why Semet-Solvay screens its five standard sizes of coke so carefully. And *after* screening, it is actually *hand-picked* to eliminate any oversized or off-quality pieces which might affect results in your cupola.

Yes, there's a size of Semet-Solvay coke just right for your foundry—it's uniform in size and quality for uniform results.

For the whole story, write today for our brand-new booklet, "The Advantages of Using Semet-Solvay Foundry Coke."

Allied Chemical

SEMET-SOLVAY DIVISION

Dept. 574-BI, 40 Rector Street,
New York 6, N. Y.

Circle No. 124, Page 139

modern castings

Golf and Wolf Rds., Des Plaines, Ill.
VAnderbilt 4-0181

Managing Director
HAROLD E. GREEN

Editor
JACK H. SCHAUM

Editorial Staff
GEORGE A. MOTT, *News Editor*
KEITH L. POTTER, *Production Editor*

S. C. MASSARI, *Metallurgy*
H. J. WEBER, *Safety, Hygiene and Air Pollution Control*
R. E. BETTERLEY, *Education*
H. F. DIETRICH, *Industry*

Business Staff
DORIS LARSON, *Advertising Sales Liaison*
MARY MCLEAN, *Advertising Production Manager*
ELAINE WALTERS, *Reader Service*

District Managers
DWIGHT EARLY & SONS CO.—Midwest
221 N. LaSalle St., Chicago 1
CEntral 6-2184

C. A. LARSON—Eastern
254 W. 31st St., New York
LOngacre 4-4285

JOHN ASHCRAFT—European
67 Ave des Champs Elysees
Paris 8, France

Published by
American Foundrymen's Society

GENERAL MANAGER
WM. W. MALONEY

Let's look at...

BUYING POWER—AND AFS "INFLUENTIALS"


H. J. Rowe

TWO EVENTS of vital importance to the metalcasting industry took place this last month. Both reflect the tremendous influence of MODERN CASTINGS' audience — contributors and readers.

First, there was the meeting of the AFS Technical Council — a 31 member super-steering committee of AFS technical activities. Each of these men is the chairman or vice chairman of a major technical division or general interest committee. They represent a 600-man team with technical depth covering every segment of the metalcasting industry. A formidable group? Yes! The 31 members each year guide the search for important developments and improvements in metalcasting. The data which they obtain on what is new and important are published exclusively in MODERN CASTINGS.

In reality, all these are *ace reporters* for the magazine. Heading the group is Howard J. Rowe, an "influential" chairman of selected "influentials" in the industry.

Also, last month the AFS Chapter Officers Conference was held. Here, truly, is another key leadership group. These leaders are the grass-roots "influentials" of the industry. You will be interested in one of the results of a secret poll taken among this group. Of the foundrymen present, 82 PER CENT reported they have a voice in the purchase of products.

When you couple this important fact with the new product needs and market opportunities springing out of new technological developments, it is easy to understand why the magazine you read is a vital, newsy publication for "influentials" in both the scientific and product phases of metalcasting.

Harold E Green

Equipped with New #900 Series Aluminum Alloy Mechanisms.

ADAMS CHERRY EASY-OFF FLASK

MAKE REAL SAVINGS FROM THESE ADVANTAGES!

CHERRY EASY-OFF FLASKS are of proven design and construction.
CHERRY LUMBER is the finest available, carefully selected and thoroughly air dried.

SIDES AND ENDS finished 1⅛" on all standard size flasks. 1¼" and heavier on flasks of larger perimeters and greater depths.

SOLID CORNERS are machine dovetailed and maintained in rigidness through dipping in "Hot Glue" and machine locking.

ALUMINUM ALLOY TRIMMINGS are also used on Adams Aluminum Easy-Off Flasks when specified.

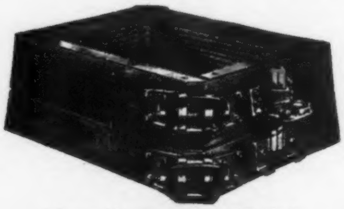
OPERATING MECHANISMS are identical with those used on the Adams Aluminum Easy-Off Flask and incorporate the same simple adjustment and reversal of locking position.

STEEL PROTECTING STRIPS are standard equipment at top, bottom and parting. Aluminum strips available upon request at no extra charge.

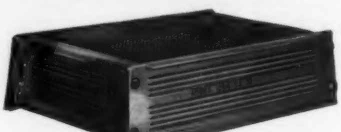
HANDLES AND TRUNNIONS are available when specified, Tee Iron Trusses if required.

PIN AND EAR ARRANGEMENT available to interchange with present pattern plate guides.

A COMPLETE LINE. Adams flask equipment meets your requirements in practically all methods of production. Before you invest, get the Adams story. Write today for our big profit-making catalog.



Adams Aluminum Easy-Off Flask



Adams Jackets, Cast Iron or Aluminum

The ADAMS Company

ESTABLISHED 1883

MOLDING MACHINES and FLASK EQUIPMENT

700 FOSTER ST., DUBUQUE, IOWA, U.S.A.

Circle No. 125, Page 139

Around the World with Modern Castings

EUROPE

Science scouts are overrunning Europe in a technical prospecting stampede rivaling the Klondike gold rush. American companies are sending key men overseas on whirlwind industrial tours, employing foreign consultants, sponsoring research in foreign universities, studying technical literature, establishing cross-licensing, and setting up European subsidiaries. A few American firms making metalcastings or selling to the foundry industry are getting into the act. You don't have to look far to see the European influence in the American foundry industry—CO_2 process, shell molds and cores, air-set cores, water-cooled cupolas, etc.

JAPAN

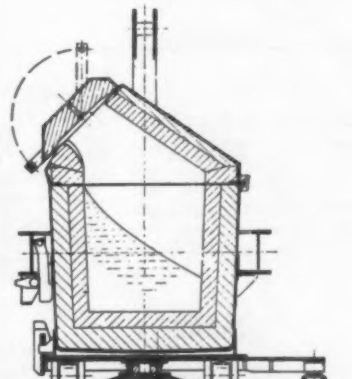
Steel casting industry is using induction stirring on most large arc furnaces. Oxygen is being used in arc furnace melting of alloy and plain carbon steel to improve melting efficiency, lower costs, and improve quality.

UNITED STATES

Fuel cells are being developed to operate material handling equipment. In three to five years industrial lift trucks will become independent of bulky electric storage batteries. **Instead, a low cost zinc-oxygen fuel cell will provide enough power to keep a fork-lift truck on the move for 16 to 24 hours.** The cell, only the size of a milk bottle, can then be chemically revived with relative ease. Many other applications are being looked at by the military and automotive industry. The compact features of this new concept are stimulating imaginative applications needing such a portable electric power generator.

GERMANY

And now it's the "Shaking Ladle" for speedy efficient desulphurizing and/or carburizing of acid cupola iron. High sulphur iron is tapped or poured into Shaking Ladle which is insulated with firebrick and inner lined with corundum. Cover fits over ladle opening. Ladle is set on a turntable (see illustration) and rotated at 60 rpm with an eccentricity of 2.4 inches. Motion of metal bath is sufficiently turbulent to provide good mixing action with lime addition. **Three to 15 tons of iron can be treated with 2 per cent lime and in 10 minutes sulphur will drop from 0.20 per cent down to 0.01 per cent.** Coke breeze can also be added to raise carbon. Some soda is added to aid slag removal after treated metal is poured. Process is particularly suited for ductile iron production and lets cheap raw materials be used in the cupola.



Around the World . . .

INDIA

The National Chemical Laboratory has developed a process for paint and varnish manufacturers in India to produce an air-hardening core oil as a less expensive substitute for the imported type. The oil binder is prepared by a special polymerization technique from double boiled linseed oil, specially treated dehydrated castor oil, and modified resin.

BELGIUM

Closer than you think is the process of producing gray iron and steel castings directly from iron ore. Albert De Sy, professor at the University of Ghent, has designed equipment capable of making liquid cast iron at $40 to $50 per metric ton. Investment should run close to $30 per annual metric ton of liquid iron.

Process involves: (1) Iron ore is charged into molten metal bath of iron on one side of double hearth induction furnace; (2) carbon is added to molten iron in other hearth; (3) carbon saturated iron migrates through bottom channel connecting the two hearths; (4) iron oxide is reduced by the carbon, releasing carbon monoxide; (5) when reaction is completed the iron ore has been reduced to molten metal ready for final alloying and casting.

Process has every indication of being competitive with conventional existing iron and steel making procedures in the very near future. Eliminates completely the need for pig iron and scrap!

SWITZERLAND

The fabulous new foundry of Sulzer Bros., Ltd., in Oberwinterthur was built for tomorrow as well as today. Read in this issue (page 30) about their electronic punch card control of heat treatment, sand elutriation for custom sand blending, and many other innovations that keep them competitive at all production levels.

AUSTRIA

The basic-oxygen (L-D) process can produce any grade of steel made efficiently in the open hearth. **Austrian steel makers predict that eventually the principal steel melting units will be basic-oxygen and electric-arc furnaces.** High quality scrap from the oxygen process makes excellent charge material for the electric furnace.

HOLLAND

A new hot strength testing device for foundry molding sands and washes makes it possible to quickly evaluate mixes. A semisphere, three inches in diameter, is formed of the material under investigation. Specimen is subjected to high temperature and surface reaction produces a visual indication of what will happen when sand mold and hot metal meet. Certain carbon additives and a sodium silicate wash showed up favorably under this test.

RUSSIA

Compression casting is a novel sand-permanent mold casting method for large, thin-walled parts—ailerons, wing fuselage sections, automobile hoods, side and bottom panels of railway cars, and boat hulls. Hinged mold halves are "booked" after metal is poured into open mold. Process can be used for all metals. More on this later.

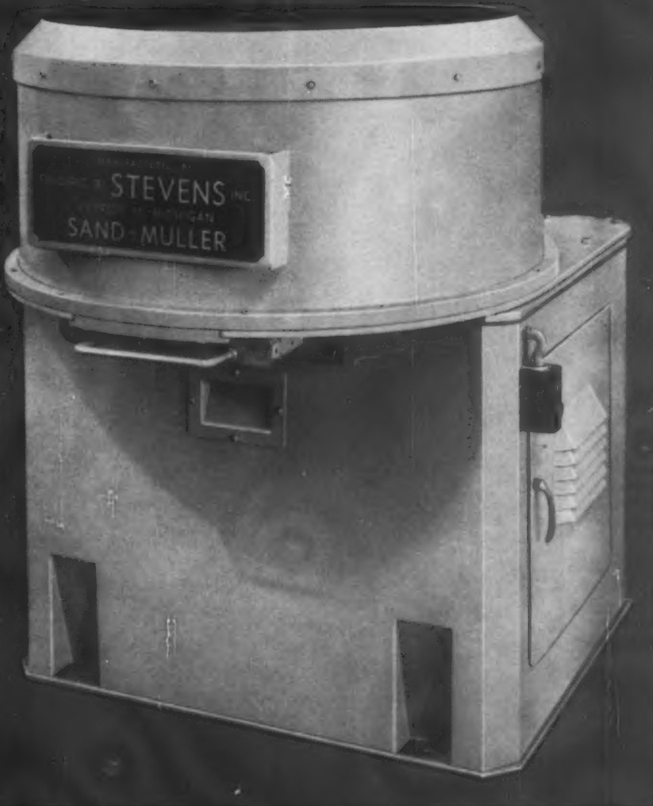
JAPAN

In Japan 93.6 per cent of the steel casting tonnage is now produced in electric furnaces. Basic furnaces are employed most widely because the industry depends heavily on imported scrap steel for its melting stock. Productivity is another serious problem. **In 1958, productivity per worker per month was only 1.197 tons of steel castings and average monthly wages were $61.60.**

See for yourself how the

NEW STEVENS MULLER

CUTS FOUNDRY COSTS!



LOOK AT THESE FOUNDRY-PROVED FEATURES!

IT'S FAST—thoroughly mixes a uniform batch in less than two minutes.

IT'S COMPACT—occupies only seven square feet of floor space.

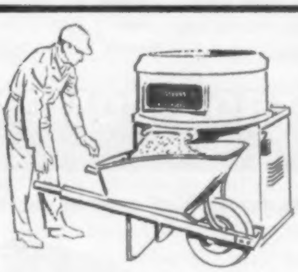
IT'S ECONOMICAL—initial cost and maintenance requirements are low.

IT'S CONVENIENT—four-foot height permits easy hand loading. Unique overhang design allows fast discharge and easy accessibility.

IT'S RUGGED—field-tested to give extra-long, trouble-free service life.

IT'S VERSATILE—provides superior performance with all types of binders.

- ***Fast efficient batch mixing***
- ***Easiest loading and unloading***



Write today for complete information on this remarkable, new foundry equipment. It's available for immediate delivery. Remember, too, that Stevens is your best source for all your foundry facings, equipment and supplies.

EVERYTHING FOR THE FOUNDRY

frederic b. **STEVENS, inc.**

DETROIT 16, MICH.

BUFFALO CHICAGO DETROIT CLEVELAND
INDIANAPOLIS MILWAUKEE NEW HAVEN SPRINGFIELD (OHIO)

Circle No. 126, Page 139

Reader Opinions and Ideas . . .

Rough Casting Surface

Editor's Note: *A letter in March issue of* Modern Castings *from* S. *Ramamurthy solicited comments on influence of casting surface roughness. Here is a reply.*

Casting surface roughness does seem to have an influence on the rate of heat transfer from the solidifying casting, since it affects the mold-metal interface temperature. It is accepted that the interface temperature has a significant influence on the rate of heat transfer and the solidification time. All other factors being the same, an ideal thermal contact at mold-metal interface is likely to develop a higher interface temperature and lead to a faster solidification.

A metal (or alloy) with low surface tension tends towards an ideal thermal contact at the interface. A metal with high surface tension is likely to develop an isolating air-gas film at interface and decrease the thermal contact. (But this effect is counterbalanced to a large extent by radiant heat transfer in case of a high melting metal.)

Most of the calculations of solidification time are based on the assumption that the interface temperature remains constant during the solidification and lies close to the solidification temperature. Thus the solidification time cannot have in reality a value noticeably less, even when roughness of the type promoting thermal contact is existing.

Since the effect of roughness is same on the heat transfer from the riser as well as the casting, the dimensions of the riser, calculated by using values of geometric area for both casting and riser, should prove correct. However, the absolute solidification time may not be exact.

N. R. Paramhansa
Freiberg
Germany

3-M's

I was especially pleased with the article on "Modernization, Mechanization, Maintenance," in the April issue of Modern Castings. Mr. Lich should be complimented on this fine, well illustrated article. We need more articles of this caliber.

I especially liked his point that the "M" for maintenance is just as important, if not more so, than modernization and mechanization in the found-

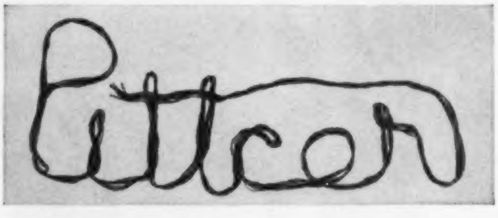
Continued on page 14

Who aimed straightest

Can you remember what you saw

HOW MANY ADM WASHES CAN YOU REMEMBER?

Ten types where exhibited as an example of the wide variety available from ADM. Actually there are many more to meet your most exacting wash requirements.



REMEMBER THE FIBER GLASS ROPE THAT CHANGED INTO CORE WIRE?

It spelled its own name to prove its flexibility . . . to show how it could be formed into intricate shapes . . . to emphasize its wire-like rigidity after exposure to heat.

REMEMBER THE CORE THAT LOOKED LIKE A TUBA?

Pohlman Foundry Co., Buffalo, shipped core and casting to Philadelphia as living proof that with CHEM-REZ, ADM's new chemically-reactive resin, superior cores could be made in minutes . . . entirely without baking.

REMEMBER THE ADM "WEIGH-BUGGY"?

. . . maneuverable hopper on wheels that makes batching and hauling a cinch.

Circle No. 129, Page 139

Reader Opinions . . .

Continued from page 10

ry. Material handling, that is, moving any kind of material from one position to another, is one of the most costly items in a foundry today. This was well emphasized by your recent article quoting the enormous tonnage of material moved to produce one ton of good castings.

F. W. Shipley,
Foundry Manager
Caterpillar Tractor Co.
Peoria, Ill.

On the Map

The July 1959 issue of Modern Castings had on page 22 a map entitled, "How the United States Looks to the Steel Casting Industry." This to me was a masterpiece and had many practical applications.

Have you ever made up a drawing of the United States, showing how the United States looks to the aluminum or magnesium industry? If so, we would appreciate a copy.

Webster J. Daly
Daly Industrial X-Ray System
Los Angeles

Besides the map showing distribution of steel casting industry, Modern Castings *published one for gray iron castings in April, 1959, and one for malleable iron in December, 1959. Maps for aluminum and magnesium are under preparation but have not yet been published.*

Nomograph Needed

In June 1949 American Foundryman you showed a nomograph for determining capacities of iron foundry ladles. The ladle capacities ran from 500 pounds of iron to 8000 pounds.

Would you have available a nomograph for steel ranging from 100-8000 pounds?

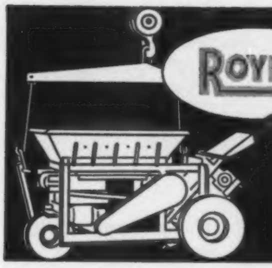
Incidentally, we have found that a cubic inch of molten steel weighs approximately 0.245 pounds.

The staff at this plant reads your valuable magazine monthly and derives a great deal of benefit from the many informative articles.

Any help that you can give us with the nomograph will be appreciated.

C. W. Farrar,
Chief Metallurgist
Fahralloy Canada Limited
Orillia, Ont.

Editor's Note: *Because of the relatively crude limitations of accuracy placed on measuring weight of metal in the ladle with this nomograph, you*



SAND CONDITIONING TOPICS

PUBLISHED BY **ROYER**, MANUFACTURERS OF THE FOREMOST IN SAND CONDITIONING EQUIPMENT

ROYER OFFERS A PRACTICAL SOLUTION TO HOT SAND PROBLEMS

In today's foundry operation, time is probably the most costly element the superintendent must deal with. Sand used for today's casting must be conditioned and ready for use tomorrow. This frequently means sand conditioning at temperatures ranging up to 300° to 400°F.

These destructive high temperature operating conditions seem to plague every foundryman. Foundry equipment suppliers have offered many possible solutions—cooling towers, shake-out belt cooling, water cooling, rotary cooling, bin cooling, etc. But probably no manufacturer has offered more thorough cooling per dollar of invested capital than that obtained with Royer equipment.

All Royer Foundry Units employ the famous Royer Belt Combing Principle. In operation, a combing and mixing action takes place in the feed hopper. This breakdown of the hot sand mass releases the hot gases as the first step

in Royer Cooling. Further cooling of the individual sand particles takes place as the conditioned sand is discharged in an open stream. And finally, the sand heap, now open, light and fluffy, continues cooling at a very rapid rate.

There is a Royer Foundry Unit to solve every sand conditioning problem. Your inquiry is invited. We promise prompt reply—without obligation.

THERE IS A SAND CONDITIONING SYSTEM TO FIT YOUR BUDGET...

Here is a positive cost-cutting sand conditioning system that falls within the budget limitations of the small or medium semi-mechanized foundry. It delivers better sand without adding to time or manpower requirements, and without the expense of complete mechanization. It gains the advantages of fluffing after handling, as the final step at the molding station.

Teamed with front-end loader, this Royer NYP-E Portable moves from floor to floor in this grey iron foundry. What used to be caked, packed sand from mulling is now a cool, fluffy pile.

An integral part of this practical system is the Royer Model NYP-E Sand Separator and Blender. It can be moved swiftly from station to station, delivering cooled, aerated, fluffed, perfectly conditioned sand right where it's wanted. With this Royer you can really get all the advantages of central system sand control.

Your system is probably "different." There's still a versatile unit of the Royer "NY" Series to fit it . . . and improve it. As a stationary model, the "NY" will fit into a conveyor system, or can be installed to take the discharge of stiff sand directly from your muller. However you use it, the Royer vastly improves sand, saves time and money, improves yield and quality of castings —all at a fraction of a cent per ton of sand.

We'll be happy to have an experienced, foundry-wise Royer agent call to help you work out the system that's best for your operation. Or, if you prefer, we'll rush you a copy of Bulletin NY-54, giving further information about these units and how you will benefit from them. When you're convinced, *you* can call in your Royer agent and take the first step towards better sand with a Royer system.

ROYER FOUNDRY & MACHINE CO.

ROYER

155 PRINGLE STREET
KINGSTON, PENNA.

☐ Tell your agent to call.
☐ Rush me a copy of Bulletin NY-54.

NAME ____________
COMPANY ____________
ADDRESS ____________
CITY ________ ZONE ______ STATE ______

Circle No. 131, Page 139

would probably be safe in using it for steel as well as iron. By using a weigh scale you could recalibrate the weight readings on the center ordinate if there was any marked difference between your steel weights and the one shown for iron.

Thanks For Coverage

Enclosed find eight photos taken at the Chicago AFS Chapter monthly meeting, April 4, 1960. Mr. Ed Greenlees of Kensington Steel Co. tape recorded this presentation which was on the subject of "Air Set Cores". This will be made available to AFS Tape Library as soon as we are able to duplicate it.

May we congratulate you and your staff in publishing all the photographs for each of these meetings. I'm certain it will help the Chicago Chapter and its many members.

George Di Sylvestro
Director of Foundry Research
American Colloid Company
Skokie, Ill.

Editor's Note: *Nice work, George. Of course you know we can't always use every photograph you boys send us, but the Chicago Chapter certainly seems well pleased. This should inspire some of the other chapters to get on the ball and get in the book.*

Pie Chart Lost

In your April Issue of Modern Castings, page 22, there was a pie chart with information on total number of employees and foundries in the United States.

We have found this article very interesting and planned on putting it to good use in our Research Department.

We now find that we cannot locate this book. Is there any way of getting another issue of the Modern Castings or possibly just a copy of this article?

D. Flaim
Crucible & Refractories Div.
The Joseph Dixon Crucible Co.
Jersey City, N. J.

Editor's Note: *It's always encouraging to know our editorial projects are being put to good use. Your last copy is being replaced by return mail.*

Tear Sheets Wanted

In the June 1959 issue of Modern Castings, an article was published on "Copper in Cast Iron" by Albert De Sy.

We are very much interested in this article and would like to obtain three or four additional copies of this particular issue of the magazine or ot the article.

A. R. Frenette, President
Midwest Foundry Inc.
Wichita, Kans.

Editor's Note: *Complimentary tear sheets were mailed the day we received your letter.*

Overseas Request

We are interested in obtaining a copy of the article, "New Polymer Sand Binder," by J. L. Dewey and T. J. West, published in the November 1959 issue of Modern Castings.

Please mail to our Library Division, attention of Dr. Behmenburg, together with your invoice in duplicate.

We thank you in advance for your kind cooperation and remain

Kalle Aktiengesellschaft,
Wiesbaden-Biebrich,
Germany

Editor's Note: *Tear sheet of article is on its way via air mail, no charge. Glad to assist our overseas foundry friends.*


HAPPY BIRTHDAY

SUMMER, SWEAT, AND SCOTCH

by HERBERT J. WEBER

When a man is in a hot environment, the chief way he can cool himself is by evaporation of sweat.

Evaporation of moisture from the skin's surface causes heat to be removed from the body. All of us have experienced this cooling sensation when standing in front of an electric fan. The air blown by the fan is no cooler than the surrounding air. Yet we are cooled because the moving air has increased the rate of evaporation.

A second but far less important way of cooling oneself is by drinking cold, low-calorie liquids.

A third cooling technique, popular but ineffectual, is the consumption of alcoholic beverages. Such drinks, no matter how chilled, will make you warmer because alcohol burns inside the body, without flame of course, thus giving off heat. Two ounces of 100 proof whiskey will give off about 668 Btu. This is enough to raise about two and a half quarts of water from 70 F. to the boiling point.

Man can cool himself in other ways such as jumping into a pool of cold water or packing himself in ice. But then he is no longer in a *hot environment.*

These facts lead us to some further considerations. Four major factors that directly influence comfort are:

1) Air temperature (dry-bulb)
2) Radiant heat
3) Relative humidity (wet bulb temperature)
4) Air movement

The effect of air temperature is obvious; and that of radiant heat was described previously (MODERN CASTINGS, August, 1957). So, let us confine ourselves to relative humidity and air movement.

Usually the atmosphere does not contain the full amount of moisture to saturate the air. The ratio between the amount of moisture actually present and the amount necessary to produce saturation at the existing temperature is called the relative humidity—not the absolute humidity.

With a given moisture content, a rise in air temperature will lower the relative humidity because hot air can hold more moisture than cold air. So the atmosphere will feel drier. On the other hand, a fall in temperature increases the relative humidity for the *same* moisture content.

If the air is not saturated, blowing air on a man will accelerate evaporation of sweat and he will be cooled. But even here the law of diminishing returns applies.

In the table, note that when the air velocity is doubled (ratio 1 to 2), the evaporative capacity changes only 1 to 1.3. A velocity ratio of 1 to 6 results in an evaporative change of only 1 to 1.9—it has not even doubled! Thus, if you increase the air velocity six fold, from 500 to 3000 feet per minute, the amount of heat removed (Btu per hour) from the man has not even doubled.

What do these facts tell us about hot weather?

1) We can't control the humidity in a foundry except by air-conditioning. Spot air-conditioning is in use in some plants.
2) For some intolerable operations, we can put men in air-conditioned suits. This is not practical in many cases.
3) We can eat low calorie meals; at least for breakfast and lunch.
4) We can drink plenty of cold water but remember to replace salt lost through perspiration.
5) We can avoid alcoholic drinks.
6) We can use "man-cooler" fans, knowing the point of diminishing returns.

Air Velocity		Maximum Evaporation Capacity	
Ft/Min	Ratio	Btu/Hr	Ratio
500	1.0	2050	1.0
1000	2.0	2650	1.3
1500	3.0	3100	1.5
2000	4.0	3425	1.7
3000	6.0	3980	1.9

Occupational Illness

by H. F. Dietrich

The body of modern man is obsolete when measured in terms of the strain placed on it by modern industry. As a result, our hospitals—especially our mental institutions—are overflowing with patched up remnants of humanity. From the executive who becomes convinced that he understands statistical methods to the swing grinder jockey who imagines himself a second Caruso, each places on his body a strain for which it was not designed.

One of the few phobias inherent in the human infant is the fear of a loud noise. To the primitive man, the cracking of a twig meant danger. Over thousands of years, the human ear and nervous system have developed a sensitivity to sharp noise. Biologically, man certainly isn't constructed to withstand the discordant clamor of a foundry chipping room.

The inner ear hammer is bounced against the anvil until the whole structure gives under the strain. The delicate nerves attached to this mechanism are overloaded until they rebel and ring constantly when the outside noise stops. Man might have overcome his inherent fear but he has not been able to change his physical structure to withstand the pounding of modern industry.

Noise isn't the only pressure of modern industry designed to blow the human fuse. There is the case of the young engineer I met while trouble shooting for a little foundry in the midwest. After graduation, he established a name for himself with money making—ideas and a drawing board. Then came the call to bigger pay in the big city where he could command $500 per month.—To inform those of you who haven't lived through those times, $500 per month was good pay in 1928.—Anyway, this drafting board da Vinci found that no matter how much he made, it cost him $100 more to live.

Being a bright young man, he decided to become a boy wonder of Wall Street. This was a fashionable occupation at the time. He learned about common stocks, bull markets, grain futures, margin buying and ticker tape. There was only one flaw in his education. He didn't learn about margin selling.

Early one fall morning he awoke in a chaotic world. Prospective morgue slab occupants, gift-wrapped in ticker tape, were passing his sixth floor window on their way to the street. Boy wonders could be scraped off the sidewalk in front of almost any building having over ten stories. Our hero rushed to the street, read the tape and tried to put his Kentucky stock holdings back on the board by personally consuming all of its production. This earned him a straight jacket and a session taking the cure.

When I met him, he was working in the shakeout pit of the foundry. His washed out, blue eyes reflected the frustration of ages. Although his hands still retained their skill with the T square and the triangle, he was unable to retain or follow any idea for more than five minutes. Looking at this broken, grimy wreck of humanity, one felt that fate would have been kinder if it had allowed him to go for a walk out of a tenth story window.

We are using a five hundred thousand year old body in a hundred year old climate of discord and frustration. If we can't change the obsolete equipment, we will have to modify the climate to avoid filling our hospitals and institutions with the remnants of broken human wreckage.

METALGRAMS

UNION CARBIDE METALS

. . . news about "Electromet" ferroalloys and metals

JULY 1960

BETTER MACHINABILITY -- Polls of gray iron castings users have indicated that they rate good machinability as "extremely important." Foundry men are improving the machinability of their castings by inoculating iron in the ladle with "SMZ" alloy. This strong graphitizing inoculant eliminates chilled corners and edges that cause excessive tool wear and breakage in the machine shop. As much as 25 per cent faster machining rates have been reported. Only 2 to 4 lbs. of "SMZ" alloy per ton generally eliminates chill. Further facts can be obtained by writing for a 16-page booklet, F-4604C.

* * *

PROMOTES UNIFORMITY -- Many foundries use small amounts of chromium to improve the uniformity of gray iron castings having light and heavy sections. Up to one per cent chromium will stabilize a pearlitic structure, eliminating soft spots caused by slow cooling in heavy sections. When properly balanced with silicon, low-chromium irons can be kept free of chilled spots caused by rapid cooling in thin sections. Union Carbide Metals offers several chromium alloys for such additions, including high-silicon grades to neutralize the chilling effect of chromium. Your Union Carbide Metals representative will be glad to give you further details.

* * *

BETTER HANDLING AND STORAGE -- Improved packaging techniques allow more efficient handling and storage of ferroalloys in the foundry. Heavy-gauge steel drums assure safe storage and protection of alloys against contamination, rough handling, and mechanical loss. Wooden pallet boxes provide a practical and low-cost means of transporting and storing large quantities of material. So do flat pallets with corrugated wrappers that are used to ship some types of "EM" briquets. These pallets are easily handled by fork lift or overhead crane.

* * *

AT YOUR SERVICE -- Improved alloys and packaging techniques are under constant study at Union Carbide Metals. Experienced materials-handling representatives work directly with metal producers to help determine the most efficient and economical types of alloy packaging and handling in individual plants. Their recommendations on traffic, handling, storage, and usage often result in big savings in money, time, space, or material.

* * *

NATION-WIDE FACILITIES -- To meet the demand for a wide variety of alloys and metals, Union Carbide Metals maintains an efficient warehouse and distribution network to serve metal producers throughout the country. Stocks are maintained at 6 plants and 26 warehouses conveniently located near major metal-producing centers. Rail, truck, barge, and boat shipments speed products to customers' plants. Your Union Carbide Metals representative will be glad to give you further information about the products and services described above. Ask for the article, "Electromet Alloys...When, Where, How You Need Them," in the Winter 1959 issue of UNION CARBIDE METALS REVIEW.

* * *

UNION CARBIDE METALS COMPANY, Division of Union Carbide Corporation, 270 Park Avenue, New York 17, N. Y. In Canada: Union Carbide Canada Limited, Toronto.

"Electromet," "EM," "SMZ," and "Union Carbide" are registered trade marks of Union Carbide Corporation.

Circle No. 137, Page 139

TRENDS IN EDUCATION

Teaching or Telling?

by Ralph Betterley

There is a lot more to "teaching" than just "telling." And we should never lose sight of this point. In a football game it's the "touchdowns that count" . . . in the foundry it's the "castings that count" . . . and in achieving these end results it's the "teaching that counts."

The fact that the metalcastings industry plays such a vital role in the present industrial world today has only been possible because of successful teaching in one form or another. The horizons reached by our foundry industry in the next quarter century will also largely depend on the quantity and quality of teaching taking place relative to metal castings.

With teaching so important, let's take a broader look at this often misused and misunderstood term. Last month, in this column, we briefly discussed "communications." Successful teaching implies sound communications in almost utopian form. However, the converse of this is not always true. In many instances a speaker or writer may have communicated well with his audience yet little teaching has transpired. Why is this true? Again, consider the original thesis—the end result. Successful teaching must achieve some end results—stimulate further study—promote specific application or experimentation—be used in problem solving and additional technical research.

A good student may have "learned" or become acquainted with certain information from a "teacher." Yet, if he does not use or apply this material, teaching has not been fully realized. Whose fault is this? Perhaps the teacher's; for he must be so dynamic, challenging, articulate, and convincing in his presentation as to motivate the recipient into action. Granted, the student in the above instance is not completely free of blame. The good student should and will apply new information; however, the teacher undoubtedly plays a prominent role in accomplishing this.

In the AFS Training and Research Institute courses, every attempt is made to "teach" course participants. Students are encouraged to pin-point and learn specific information which they can apply to their own operational problems. T&RI teachers are challenged to get the needed information "across" to achieve the desired end result. The students should also assume responsibility. In many cases they can best obtain the answers to their specific problems by active participation in class discussions. And the instructor has a fine opportunity to "teach," not just "tell."

To accomplish the ultimate in teaching, the teacher needs unusual attributes. Besides intelligence and competence he should possess qualities ranging from the side-show "barker" and magician to the orator. And even then he must be able to develop rapport with his audience before effective communication and teaching can take place.

A good teacher organizes instructional material so as to present information in a clear-cut and logical sequence most suited to the learning process. The effective teacher uses his skills in "getting through" to his audience.

By this time you have perhaps concluded that all this applies only to the professional pedagogue lecturing to a sizable class. Such is not the case. This process applies to all foundry personnel—regardless of the number and operations involved. We should all be "teachers" and "learners" at one time or another and this exchange of information must constantly improve if new technological demands are to be adequately fulfilled. Many companies have adopted the policy of having key personnel train specific assistants under them to assume responsibilities in case of emergencies. This is good insurance against untimely personnel shortages; therefore, if assistants, learners and associates are to be adequately prepared, let's be sure we are "teaching"—not just "telling."

Here's How . . .

Metalcastings are doing a better job. Foundries are solving production problems. New products are resolving in-plant headaches. If you have an appropriate contribution for this department, send it to the editor of Modern Castings.

. . . Foundrymen on the ground are keeping missiles in the air with magnesium castings. Reliable lightweight streamlined cast shapes are essential to the operational success of this Nike-Hercules missile. Produced by Douglas Aircraft Co., this supersonic lethal weapon uses more than 200 pounds of magnesium castings. Pictured is a fairing located in the tail or booster section and permanent mold cast by The Dow Metal Products Co. Casting weighs 8 pounds, is made of AZ63A-T6 alloy.

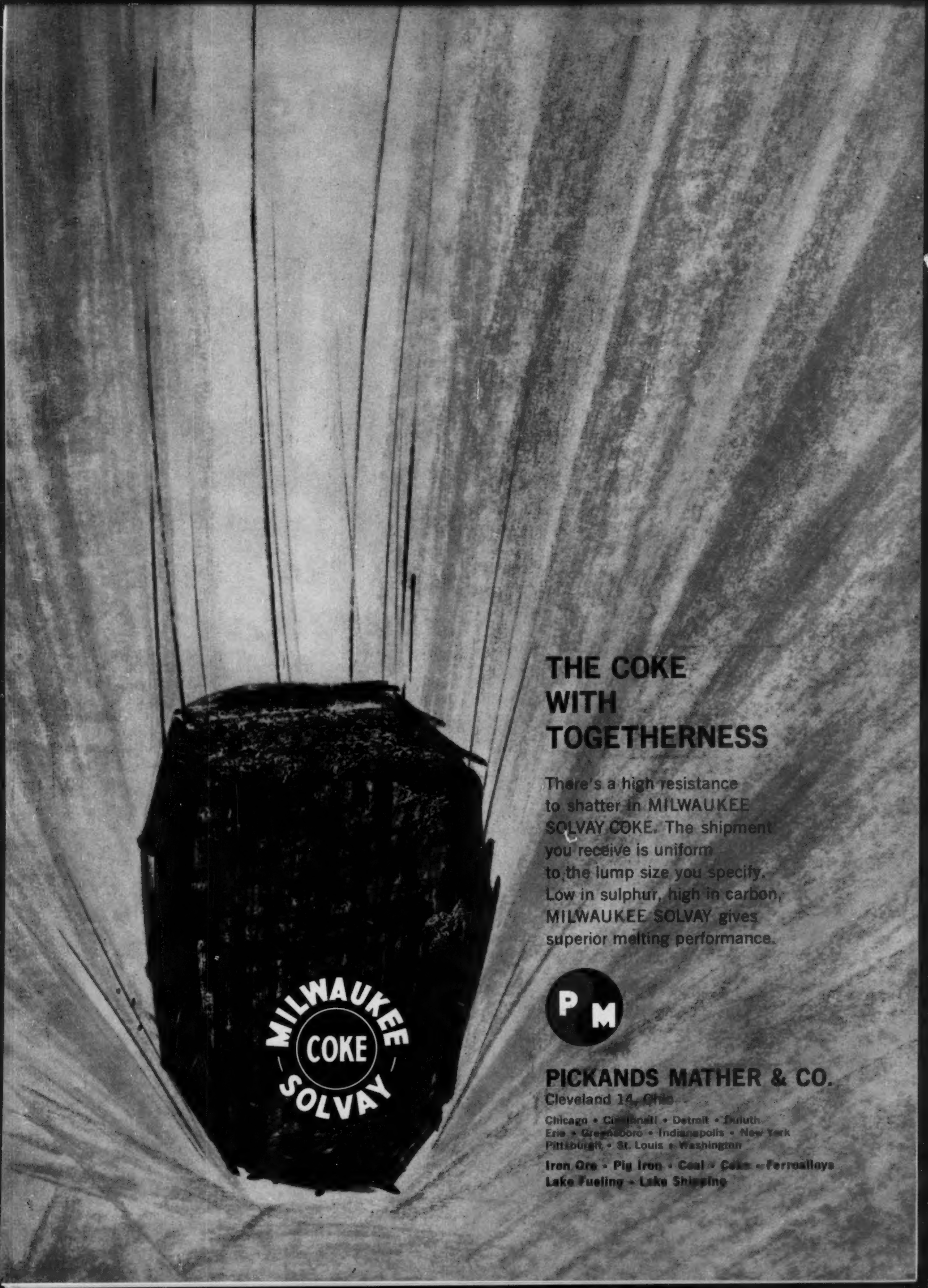
Other magnesium castings on the missile are: 29-pound pedestal structure, 19-pound booster base plate, 16-pound booster fin fitting, and 12-pound forward frame. Magnesium-rare-earth alloy EZ33A-T5 is used for four forward fins which are subjected to aerodynamic heating.

Metalcasting plants all over the country are aiding the vast aircraft and missile complex to conquer new frontiers of space and speed. No other fabricating process is so versatile as casting in its ability to produce complex configurations with economy, speed and reliability.

. . . Casting makes dough. This intrically-shaped cast stainless mixing arm has doubled production at Bealy's, Inc., a bakery in Flushing, N. Y. Cast in type CF-16F stainless steel (Alloy Casting Institute designation), the surfaces are smooth and resistant to cleaning chemicals and mechanical brushing. The complex 400-lb configuration was designed at Peerless Bread Machinery Corp., Sidney, Ohio.

. . . CO_2 process is used by Columbian Bronze Corp., Brooklyn, N. Y., to make molds for nickel-manganese bronze ship propellers. Using a wood pattern for just one blade, they first ram one segment of drag and gas with CO_2. Then cope flask is placed on drag. Cope half of blade is rammed and gassed (see illustration). Cope and pattern are drawn. Then pattern is indexed on its center post to the position for the next blade. This sequence is repeated until five-blade mold is completed. Good sand flowability permits drag to be rammed under the pattern without rolling over the flask. Benefits: 1) gaggers and reinforcing rods are eliminated, 2) deep draws present no problems, 3) rigid mold walls improve casting accuracy, and 4) casting quality is superior.

. . . 30-inch-diameter steel risers can be sliced off castings with a single pass of a new natural gas cutting torch introduced by Linde Co., Div. of Union Carbide Corp. Burns up to 3000 cfh of oxygen and 250 cfh of natural gas. Torch is also suited for gouging and pad and fin washing.



MILWAUKEE COKE SOLVAY
THE COKE WITH TOGETHERNESS
There's a high resistance to shatter in MILWAUKEE SOLVAY COKE. The shipment you receive is uniform to the lump size you specify. Low in sulphur, high in carbon, MILWAUKEE SOLVAY gives superior melting performance.
PM
PICKANDS MATHER & CO.
Cleveland 14, Ohio
Chicago • Cincinnati • Detroit • Duluth
Erie • Greensboro • Indianapolis • New York
Pittsburgh • St. Louis • Washington
Iron Ore • Pig Iron • Coal • Coke • Ferroalloys
Lake Fueling • Lake Shipping

15 Ways Your Gray Iron Business Can Grow

Selected leaders tell how they are seeking new market opportunities in a "come-back" field. Technological awakening leads to profits and marketing muscle.

1. Cheapest and most efficient way to get from the drawing board . . . to the end product is by casting in quality gray iron. To exploit this great marketing advantage foundrymen must sell their customers on the versatility and economy of this practical engineering material.—T. H. Tanner, Vice-President, Zenith Foundry Co., Milwaukee.

2. Nuclear reactor shielding . . . is an important new industrial market for quality gray iron because of its heavy mass, homogeneity, castability, economy and structural integrity. —J. N. Wessel, Metallurgist, Puget Sound Naval Shipyard, Bremerton, Wash.

3. Long term load-carrying ability . . . of some low alloy cast irons at 800 F. unfolds new market possibilities for product designs requiring elevated temperature service.—L. N. Shannon, Vice-President, Stockham Valves & Fittings, Birmingham, Ala.

4. Quality gray iron permanent molds . . . are demonstrating the suitability of this material to withstanding rigorous elevated temperature service. Our foundry uses thousands of tons of iron in making permanent molds for centrifugal cast iron pipe and static cast fittings. These molds were formerly forged alloy steel. Growth in permanent mold casting of aluminum has been paralleled by increased demands for iron molds. Gray iron core boxes for shell cores have established their superiority over all other materials. In all these applications the foundry industry itself is the growing market for its own cast products.—M. J. Henley, Vice-President, Tyler Pipe & Foundry Co., Tyler, Texas.

5. Crankshafts and camshafts . . . continue to show great promise as one of the best growth areas for quality gray iron castings. Gray iron can now be controlled to yield a combination of high tensile strength, superior damping capacity, good torsional strength, excellent wear properties, and unique fatigue resistance. These all add up to what's needed to meet requirements of the tremendous market for crankshafts and camshafts.—Donald E. Webster, Foundry Superintendent, American Laundry Machine Co., Rochester, N. Y.

6. Product reliability . . . will open more new markets for gray iron castings than any single physical property. The complex equipment of today's technology is demanding an ever-increasing order of reliability in performance. High quality castings, made under thorough process controls, good engineering, and sound management, will meet the challenge of this new reliability concept. Customers recognize that the real significant economy lies in sustained performance. Foundries that do not heed this demand not only invite failure but also do serious harm to the entire gray iron industry.—A. E. Schuh, Director of Research and Development, United States Pipe & Foundry Co., Burlington, N. J.

7. Cast iron automotive cylinder sleeves . . . represent a fast growing market potential.

Sleeves are machined on inside. But outside surface has controlled as-cast roughness which assures good bond when aluminum block is cast around the sleeve.—Charles K. Donoho, Chief Metallurgist, American Cast Iron Pipe Co., Birmingham, Ala.

8. The commercial and industrial air conditioning industries . . . offer one of the newest marketing opportunities for quality gray iron castings. Close cooperation between designers, foundrymen, and production planners has led to a new series of compressors with dimensions so close that it's possible to perform preliminary fixturing on locating points and complete machining on automatic machine tools. Production of a wide variety of compressors to meet these fabrication requirements has been one of the outstanding contributions made by the semi-production jobbing foundry to our modern-day economy.—Walter L. Seelbach, President, Superior Foundry, Inc., Cleveland.

9. Greatest market opportunities for gray iron . . . lie in the new-found ability to meet specifications heretofore thought impractical or impossible to achieve. As result of improved manufacturing and melting techniques and rigid quality control, gray iron can be cast with constant dimensional accuracy within close tolerances.—Gordon L. Paul, Brillion Iron Works, Brillion, Wis.

10. Heat and wear resistant ductile iron . . . are carving out new markets as an economical replacement for malleable iron and steel. Many of these applications are in the fast growing aluminum, glass, and plastics industries.—John O'Meara, Vice-President, Banner Iron Works, St. Louis.

11. Close cooperation and engineering assistance . . . from the foundry with the purchasing and engineering departments of the casting buyer can result in many new markets for high quality, well designed, readily machinable gray iron castings.—H. W. Johnson, Vice-President, Wells Mfg. Co., Skokie, Ill.

12. Thin section gray iron castings . . . have saved enough weight to allow gray iron to compete with light metals. This ability will lead to new applications and markets for gray iron castings.—J. O. Ostergren, President, Lakey Foundry Corp., Muskegon, Mich.

13. Hydraulic control valves . . . for earth-moving machinery have been designed in gray iron to operate at pressures over 5000 psi. Complex coring saves fabricating expense and gives uniform high strength half-inch wall thickness capable of working at these high pressures. By keeping this application from being converted to steel, the gray iron industry has strengthened its position in an important market area.—Frank Dost, President, The Sterling Foundry Co., Wellington, Ohio.

14. Most important new applications . . . for ductile iron castings are printing presses. Ductile iron is proving more economical for many parts that were steel forgings and castings.—C. R. Lindgren, President, Lindgren Foundry Co., Batavia, Ill.

15. Major increase in demand . . . for gray iron hydraulic valves can be attributed to new coremaking developments. Also, recent National Electrical Manufacturers Association Standard replaces welded motor frames with gray iron castings.—Charles F. Seelbach, President, Forest City Foundries, Cleveland.

"New Alertness Needed Today . . ."

by Jack H. Schaum, Editor

The gray iron industry has been a sleeping giant just now beginning to flex his technological muscles. The gray iron giant suddenly woke up to the realization that many of his traditional markets were being lost to more imaginative market-minded industries. A few examples of new products that nibbled sizeable bites from cast iron shipments are: plastic pipe and fittings; asbestos cement pipe; aluminum blocks, housings, pistons, and heads; steel railroad car wheels; enameled steel sanitary ware and stoves; welded machine tool beds and frames; fabricated sheaves, pulleys, and wheels; aluminum tire molds; welded assemblies of structural steel; and ductile iron crankshafts, valves, and pipes.

After reading the preceding comments by 15 prominent gray iron foundrymen, you can readily sense the

strong resurgence of an industry that was recently reeling from the impact of aggressive competition. Fortunately this is the American way—compete or perish, grow or go.

Gray iron foundrymen discovered that marketing was not a one-way street. Two could play the game. And it wasn't long before the tide turned to redesigning weldments and forgings to castings. For instance: An accounting machine handle was redesigned from an eight piece steel assembly to a one piece, shell molded gray iron casting at a cost reduction of 78 per cent.

An aluminum gear carrier for automotive automatic transmission was changed to ductile iron for 50 per cent more strength at same price. A brass valve on an agricultural liquid fertilizer was converted to gray iron because it resisted corrosive ammonia in insecticides and fumigants.

The parade of gray iron progress continues every day. The 15 leaders commenting on the previous pages mention such growth markets as atomic reactor shielding, permanent molds, crankshafts, camshafts, cylinder sleeves, compressors, and hydraulic valves.

Henry Ford once said "If it can be drawn on a drawing board, it can be cast." Foundrymen are now doing a good job of getting this message through to design engineers. Potential customers are being alerted to the capabilities and economies of gray iron castings.

It's particularly significant to see the areas in which foundries are depending on castings to improve their own metalcasting operations. Gray iron is becoming the preferred material for shell molding patterns and shell core boxes. The molds and cores made from these patterns and boxes permit accurate and intricate gray iron castings to be made to quality standards heretofore unattainable. Gray iron permanent molds are being used to shape gray iron pipe and fittings as well as a multitude of aluminum cast parts. New molding techniques are permitting these molds to be cast-to-size so little if any machining is needed. So the industry is literally pulling itself up by its own bootstraps.

Gray iron received a technological awakening just after World War II when the new metallurgy of ductile iron was born. Iron foundrymen soon discovered they had a lot to learn about cupola melting practices before they could produce controlled analyses suited to conversion into ductile iron.

A general upgrading of cupola melting technology resulted in far more scientific melting practices with a great improvement in metal quality at the spout. Soon the water-cooled cupola became an important new melting unit in iron foundrymen's hands. This versatile piece of equipment has permitted new competitive flexibility. Now a foundry can melt acid, neutral or basic in the same cupola in the same day, tapping a variety of iron compositions.

By adding ductile iron to their product bill of fare, gray iron foundrymen have broadened the gamut of physical properties into the realm of competition with malleable iron and steel. Ductile iron production has already reached an annual production level of 167,000 tons in 1959. In this same year gray iron shipments equaled 12,300,000 tons.

. . . BIG TIRE MOLD

Rubber tires on the nation's rolling vehicles means big market opportunities for our foundry industry. Pictured above is half of a rubber tire mold for off-highway equipment. It's a precision iron casting poured in sand by the Engineered Castings Div., American Brake Shoe Co., Medina, N. Y. Special techniques result in dimensional accuracy and smooth surfaces that require only a minimum of finishing. Gray iron and ductile iron are moving in and establishing a fine record of performance as a mold material for shaping rubber, plastics, glass, and metals.

Like any large object, the gray iron industry is gaining momentum slowly. But now that it's rolling the frequency of new developments should accelerate. The comments from around the country in the preceding pages are a few of the clues to new market opportunities currently being exploited. The gray iron industry is on the threshold of new technological developments that will make it even more competitive.

Principal of these is the direct reduction of iron ore to molten iron ready for casting. Pilot plants are already operating. Success at this level indicates that economic production facilities will soon be a reality. One of the most promising of these processes will soon be described in detail in Modern Castings.

A new alertness is needed today . . . you have to run fast just to keep from being buried by technological obsolescence.

Editor's Note: *We are sure there are many other examples of new market opportunities for gray iron foundries.* Modern Castings *welcomes further comments from gray iron foundrymen. Drop the editor a letter with your views on this important subject.*

FROM SWITZERLAND:

What Sulzer Put in its New Foundry

This Swiss company was built for tomorrow as well as today. Friedrich Eisermann, Sulzer Brothers Ltd., Winterthur, Switzerland, presents here seven of the most important installations his company has in its new Oberwinterthur plant:

1) Sand elutriator for custom sand blending,
2) Continuous ovens for surface dried molds,
3) Roll-over draw machines handling molds up to 22 tons,
4) Shakeout machines for 80-ton molds,
5) Blast heater for 1100 F cupola blast,
6) Medium-frequency induction furnaces with multiple coil sections,
7) Electronic punch card control of heat treatment.

Now the company has great flexibility in making castings from 200 pounds to 120 tons! It keeps them competitive at all productive levels.

A SULZER FOUNDRY at Winterthur has existed since 1834. Since that date, however, it has developed in many directions. The restricted space available at Winterthur itself did not admit of effective extension or even of a reconstruction in line with up-to-date foundry techniques. The plans prepared for the works as a whole envisaged as the most practical solution the transfer of the entire foundry plant from Winterthur to Oberwinterthur. This would enable a foundry to be erected in Oberwinterthur embodying the very latest technical progress in foundry methods and thus give scope for modern developments in the years to come.

The subdivision of the ground area which was chosen for the new foundry (Fig. 1) was partly dictated by the desire to manage with a small supervisory staff and to enable the individual production groups to exchange material and equipment freely.

Flexible Mechanization

In view of the predominance of individually produced castings and the possibility of structural alterations at a later date, a high degree of flexibility was aimed at in the choice of production equipment. Only in this way was it possible to make allowances for the varying influx of orders and the widely differing categories of castings.

Where heavy castings are produced, limitations are placed upon the use of mechanization and automation in the foundry. For this reason manual production techniques will continue to occupy a certain province of our activities even in the future. Intensive subdivision of the working processes, however, enables highly qualified personnel to be employed at all times where they are most useful. The less qualified workers are still able to perform skilled tasks, a point which is very important at a time when the problem of finding young recruits for the industry is causing some concern.

The production program determines the over-all layout of a foundry. The wider the range of castings manufactured, the greater the demand for operational flexibility.

Castings weighing anywhere from 200 pounds to 120 tons are produced in the new Sulzer foundry at Oberwinterthur. The wide discrepancy between these upper and lower weight limits will give some idea of the considerable problems with which the planning engineers were faced. The diversity of their products, however, is characteristic of the Sulzer foundries. They not only turn out gray iron and steel castings for the entire Sulzer production program but must also meet all requirements of foundry customers. The foundries must also supply castings which meet all specifications for alloyed and unalloyed, heat-resistant, nonscaling, corrosion-resistant and wear-resistant materials.

Sand Preparation Plant

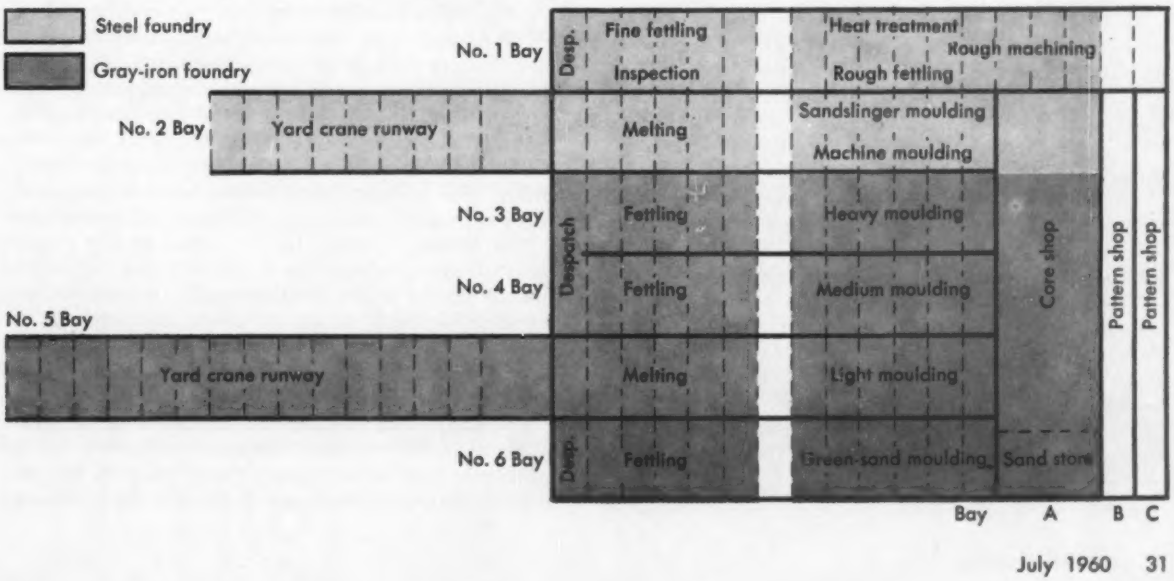
The sand preparation plant (Fig. 2), sited at the rear end of the building between the molding shops and the core shop, measures over 72 feet in height and handles up to 190 tons of sand per hour. About 160,000 tons of molding sand and 12,000 tons of core sand are prepared annually.

The molding sand preparation plant is subdivided into several sections:

- Molding sand for dry-sand casting in the steel foundry,
- Molding sand for green-sand casting in the steel foundry,
- Core sand,
- Molding sand for dry-sand casting in the gray iron foundry,
- Molding sand for green-sand casting in the gray iron foundry.

The sand preparation plant proper is supplemented by a new sand-drying plant and a quartz sand reclamation plant which can handle up to 10 tons of sand per hour. Efficient dust collection and the enclo-

Fig. 1 . . . Floor plan for Sulzer's new foundry shows facilities for production of gray iron and steel castings.



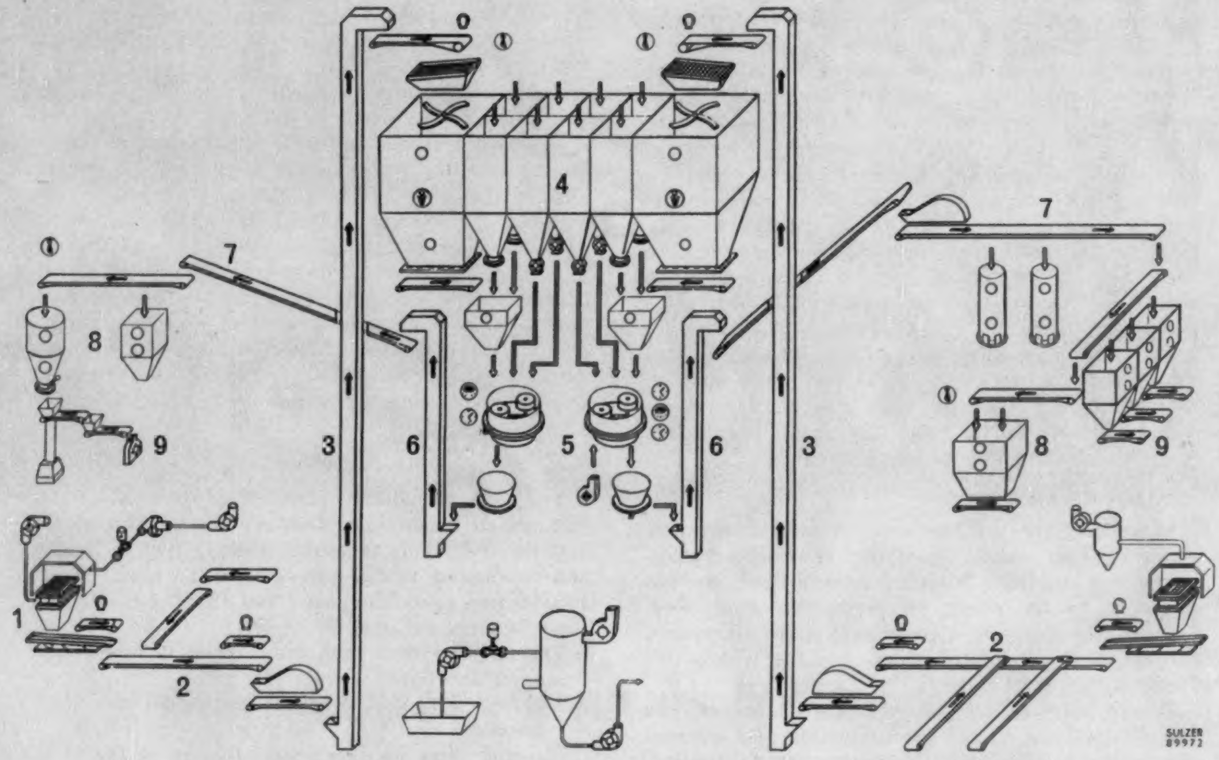


Fig. 2 . . .

Sand preparation diagram for the steel foundry.

1 Shake-outs
2 Used-sand return conveyors
3 Bucket elevators for used sand
4 Sand and binder silos
5 Sand mixers
6 Bucket elevators for prepared sand
7 Conveyor belts
8 Intermediate silos
9 Moulding stations

sure of most of the handling equipment ensure dust-free operation of the sand preparation plant.

Preparation of Molding Sand

In the sand preparation plants for steel and gray iron castings, synthetic or semi-synthetic clay-bonded molding sands are formulated according to use.

The ingredients required to make up the finished sand mixtures—used sand, new sand, binders and additives—pass through the following stages before entering the mixers:

Used Sand: The sand detached from the box* and casting by the shakeout drops through a hopper onto a shaker conveyor (1) above which the first magnetic separator is fitted to remove any fragments of iron.

From here the sand is passed on to underground return conveyor belts (2) running parallel with the molding lines. The completely enclosed design of these conveyors ensures intensive exhaustion of all undesirable dust. After receiving any strickled sand below the molding stations, the used sand passes through a cooling drum centrifuge. Here particles of iron are separated for the second time, into a bucket conveyor (3), which raises it to the silos of the preparation unit. After a third removal of any iron particles, it is discharged into the used-sand bunker (4) through a shaker screen.

New Sand: The new sand, either with a natural clay content or free of clay, comes from the central drying plant and passes, dry and cooled, via a conveyor belt serving all units into the new-sand bunkers.

Binders and Additives: It is intended to convey the powdered binders and additives to the appropriate silos by pneumatic means, so that the advantages of modern container transport can be utilized.

The Mixing Process: In the actual mixing process the various ingredients are supplied to the high-speed mixers (5) by self-controlled trucks or bucket-wheel feeders. Water is added by automatic control. The blending and kneading effects in the mixer are produced by horizontal wheels. Rapid rotation of the lifting blades causes the sand to mount up the walls.

Prepared sand mixtures are delivered to the stock bunkers of the molding stations via further bucket conveyors and belts (6, 7, 8); they pass on the way through drum centrifuges, according to their intended

*Flask

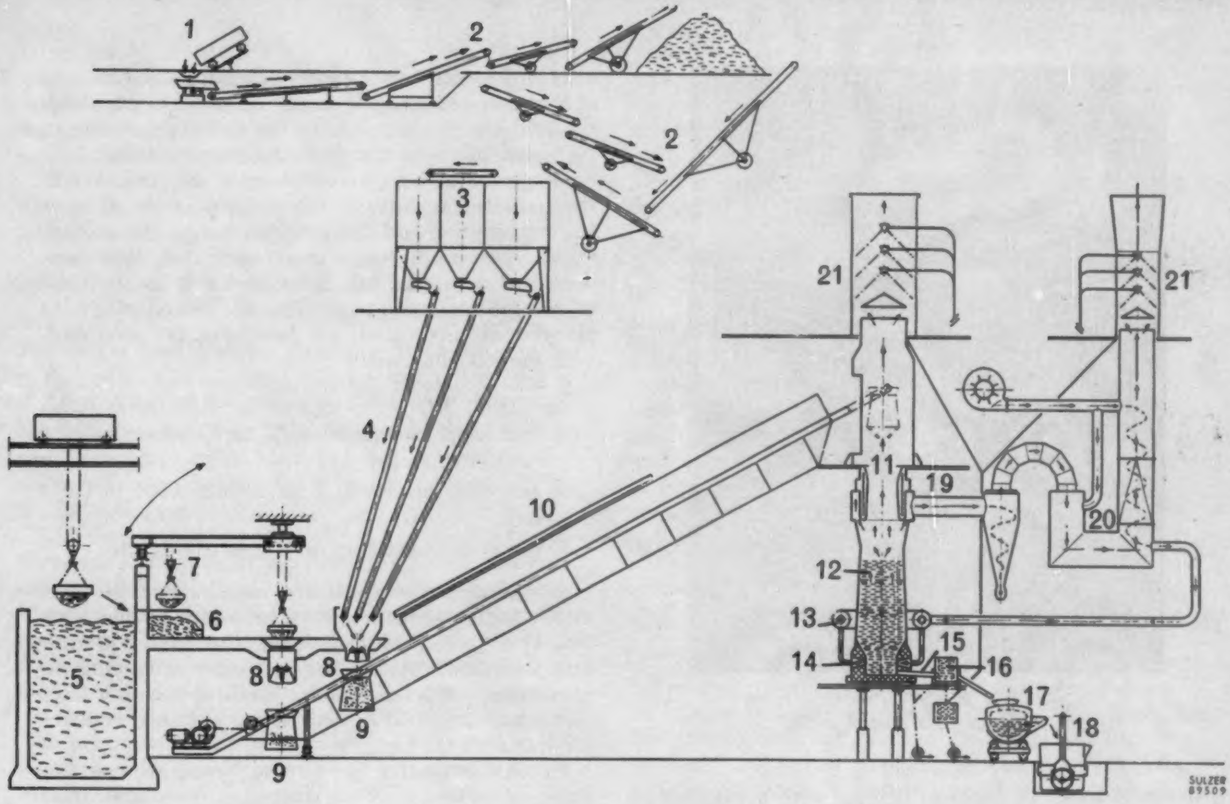


Fig. 3 . . .

Diagram illustrating cupola operation.

1 Wagon tipper
2 Conveyor belts
3 Coke and limestone silos
4 Conveyor belts to charging plant
5 Pig-iron and scrap bunker
6 Charging platform with compartments
7 Lifting-magnet crane for charging plant
8 Weighing hopper for charge material
9 Charging skip
10 Inclined hoist
11 Throat of cupola
12 Cupola shaft
13 Annular hot-blast belt
14 Tuyère
15 Iron and slag run-off
16 Slag separator
17 Receiver of 10 tons capacity
18 Pouring ladle
19 Exhaust pipe for cupola gas
20 Blast heating plant
21 Dust extraction plant

application. These preparation processes are under fully automatic control from a central electronic station and can be followed by visual indications on a luminous diagram.

The addition of the necessary water to the sand is controlled by a tester which measures the moisture content of the old sand and allows for any temperature fluctuations. The control element of this unit automatically allocates the amount of water necessary to ensure the pre-selected moisture content for the prepared sand. Sands prepared in this manner can be supplied to the molding shops with a moisture tolerance of ± 0.2 per cent.

Cupolas

The cupola installation in the Sulzer foundry (Fig. 3) comprises a water-cooled hot-blast cupola with neutral lining. It can be used either for the acid or the basic process. An uncooled hot-blast cupola is only intended for the acid process. The hearth of both cupolas has a diameter of 3 feet 7-1/2 inches.

In both units six tuyeres are arranged in the annular hot-blast belt. Both cupolas are over 76 feet in height. Each of them has a melting output of 12 tons per hour. A common receiver with a capacity of 10 tons is located in front of the furnaces (Fig. 4). The observer's attention is drawn by the extensive recuperator equipment for heating the blast and by the water-cooling system on one which has the aspect of a small blast furnace and is intended for special metallurgical processes.

The blast heating system works on the counterflow principle. The waste gases given off by the burning coke are led out of the furnace shaft, burned in a combustion chamber and passed through a recuperator in which their heat is given up to the stream of cold air flowing in the opposite direction. Blast temperatures of up to 1100 F are obtained in this way. The hot blast enables cast-iron temperatures of over 2700 F to be obtained with a smaller coke charge than previously possible.

For reasons of economy it was decided to supplement the cupola installation in the new foundry with a battery of medium-frequency induction furnaces instead of the arc melting furnaces used heretofore. This installation is placed next to the cupolas in the same bay. It comprises one crucible furnace with a capacity of 10 tons, two others of 5 tons each, and

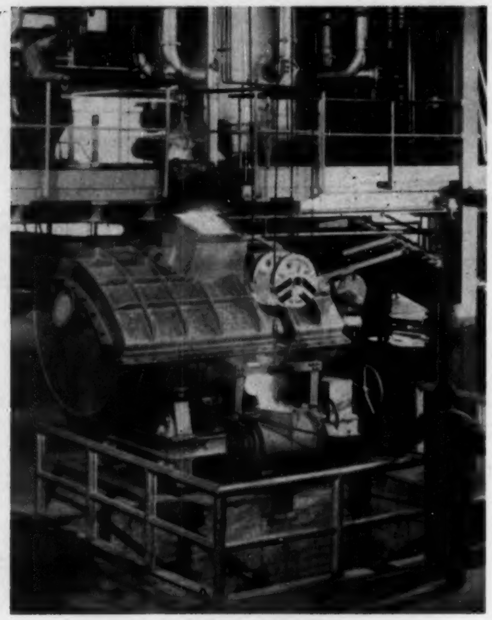


Fig. 4 . . . Molten metal flowing from receiver to transfer ladle.

one of 2 tons. All furnaces operate with a frequency of 600 cycles per second. The coils of the 10-ton and the two 5-ton furnaces are divided into three sections, that of the 2-ton furnace into two, each coil section having a connected load of 800 kc. This is the first time that this principle has been employed in a large medium-frequency induction furnace installation. The division of the furnace coils into sections enables single sections to be switched on or off, or their loads varied, in accordance with melting requirements, such as the level of the iron.

These furnaces represent a substantial increase in capacity, which is of particular importance when large castings weighing up to 120 tons have to be poured. In certain cases it is necessary to duplex the cupola iron for reasons of quality. The induction furnaces are used for adjusting the analysis, for additional alloying, or for attaining definite temperatures. The furnaces also produce various grades of gray iron, alloyed iron, and nodular iron from solid charges.

All the core-sand mixtures required in the new foundry are blended in a core-sand preparation plant situated between the two plants for molding sands. The ingredients needed for these mixtures are brought up by the belt conveyor serving all plants. Powdered materials are charged pneumatically into the bunkers above the mixing platform. Liquid ingredients will later be delivered from the stock tanks straight into the mixers by high-pressure pumps. On the mixing platform a loam-mixing machine and two or three smaller mixers for easily miscible core sands are installed. The ingredients are supplied to the mixers via scales fed by vibrators operating at a variable delivery rate. Any water needed is supplied through flow meters. Finished core sand mixtures are then transported to the nearby core shops.

The quality of castings and the proportion of rejects are largely determined by the grain structure of the core and molding sands. In order to overcome the problem of variations in the sands delivered, an elutriator has been installed at Oberwinterthur. This equipment has very recently been introduced into the foundry industry. It enables any grade of sand to be produced and deliveries to be graded according to the foundryman's requirements. A great economic advantage of this plant is that it can be used to recondition used sand from the foundry. Up to 10 tons of used sand per hour can be processed, with the following yields:

- 5 per cent over 0.051 inch (for use as body sand),
- 50 per cent coarse foundry sand from 0.013 to 0.053 inch,
- 35 per cent fine foundry sand from 0.004 to 0.014 inch,
- 10 per cent waste dust from 0 to 0.004 inch.

In comparison with existing installations, the plant at the Sulzer works has been perfected by the addition of a special grain cleansing unit and a grading unit with an elutriator. The possibility of varying the grain composition of foundry sands opens up a large and rewarding field of activity for the sand research laboratory of the foundry.

In conventional mold drying processes, molding boxes of various sizes are stacked in ovens and dried. Large molding boxes are dried by means of portable driers which are placed on the completed mold and blow hot air into it.

Experience has shown that only a limited drying depth is required in order to produce sound castings; it varies according to the nature and size of the casting between 0 for green sand molds and 6 inches or more for large castings.

From the purely economic viewpoint this means that the lowest costs are entailed by castings produced in green sand, while dried molds are more expensive.

The surface drying process is based on the fact that only a limited, optimum drying depth in the mold is necessary for a sound casting. It is obviously uneconomical to pour a casting in a completely dried mold when it can be produced satisfactorily with a smaller drying depth. The surface drying process therefore attempts to cover the intermediate range between the green sand process and the conventional, complete drying process. It is thus a finely differentiated mold drying process developed with the object of reducing costs and enabling cheaper castings to be produced.

This surface drying technique is carried out not in the large intermittent ovens of the conventional process but in continuous ovens or smaller chamber-type intermittent ovens. The cope and drag receive hot air emitted at high speed by nozzles fitted in the roof. A time schedule ensures the desired depth of drying. Sulzer dries medium and small molds in both the steel and gray iron foundries.

Molding Methods

Sandslingers are efficient sand packing machines which hurl sand into the mold centrifugally by means of a rotating wheel. Sand, brought up by the feed

system, is led to the slinger head via conveyor belts carried on two movable arms. The motor-driven wheel delivers about 0.35 cubic feet of sand into the mold per second at a speed of about 160 feet per second.

The sandslinger has only been introduced into Europe in recent years, as large quantities of well-conditioned sand have to be available. This, however, calls for efficient and thorough sand preparation equipment. In the new foundry five sandslingers handle 3-1/2 million cubic feet of sand annually (Fig. 5).

Turn-Over and Pattern Drawing Machines

Turn-over and pattern drawing machines save a great deal of labor while increasing the speed and precision of molding. They turn the molding box over after the pattern has been molded and remove the latter from the mold. The operation proceeds in the following manner:

The box containing the pattern is rolled onto the turn-over machine and secured with chains. The machine lifts the box and turns it through 180 degrees. Machine table is lowered with the box onto the roller conveyor. Chains are unfastened and the pattern is withdrawn slowly from the sand with the turn-over table. All movements are controlled pneumatically. The largest turn-over machine at Oberwinterthur will take a box weighing up to 22 tons. It is one of the most powerful machines of the type ever employed in a foundry.

Apart from this large unit there are also three small turn-over machines, each of 12 tons capacity.

Shakeouts

Modern shakeouts have been provided for all the molding shops in the new Oberwinterthur foundry. The largest is in four sections and will take boxes weighing up to 80 tons or measuring up to approximately 24 by 19 feet. Very few shakeouts have been produced up to now in these dimensions. In addition there are three smaller shakeouts of 20 tons capacity each.

The shakeout is mounted on springs and is operated by rotating eccentric weights which are driven by an electric motor. The vertical lift is 0.3 to 0.4 inches at the rate of about 1000 strokes per minute. Features of this installation are dust-extraction hoods and separators.

The medium-size shakeouts are provided with simple exhaust hoods, in the top of which a horizontal curtain of high-pressure water arrests dust. The work of knocking-out is not only carried out by the shakeouts in a fraction of the time formerly needed but also done without dust nuisance.

Heat Treatment Plant

The heat-treatment furnaces are controlled electronically by punched cards in accordance with the heat-treatment directives of the metallurgical laboratory. This advance ensures metal of identical grades with uniform properties and eliminates the possibility of human error. This furnace control system may be regarded as a fundamental advance in the technique of heat treatment.

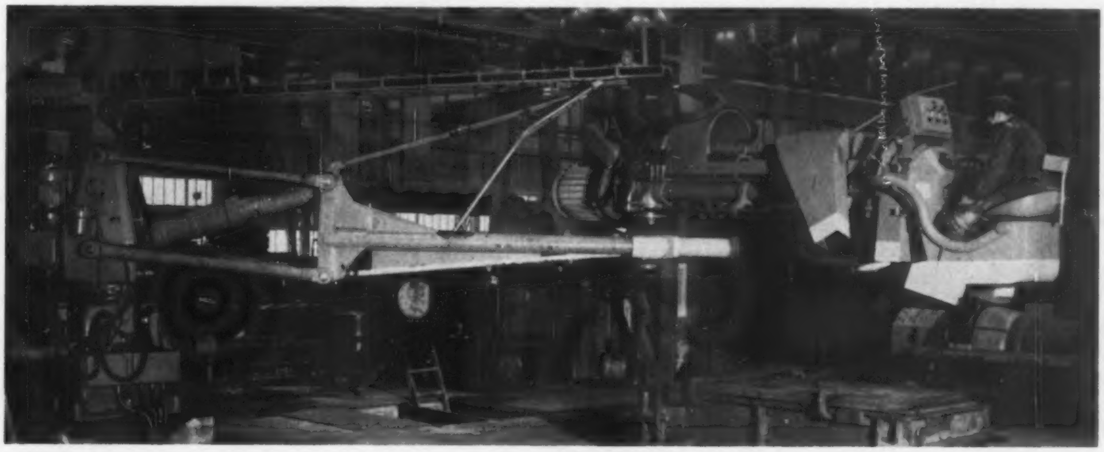
The furnaces can be used for either steel, gray iron or nodular cast iron. Oil and water baths are provided for quenching cast steel.

Conclusion

The new foundry is backed up by the metallurgical laboratory attached to it and by the Sulzer central laboratories with their staff of specialists and experts. Not only are purely practical problems solved with their assistance, but research work is carried on in the fields of foundry and materials technology in order to improve further the manufacturing processes and the quality of the castings produced.

Building the new foundry on a completely free site at Oberwinterthur and planning it in the light of the most up-to-date principles of technology, organization, and production engineering have ensured high economy coupled with improved working conditions for the operatives. Such long range thinking guarantees the high standard of Sulzer foundry products for many years to come, and at the same time represents a substantial contribution to the competitive strength of the Swiss engineering industry and to the healthy development of foundry practice in Switzerland.

Fig. 5 . . . Slingers are used in mold preparation. Five units handle 3-1/2 million cubic feet yearly.



Lifesaver for Bottom Boards

Every foundry is fighting a losing battle of heat versus wood bottom boards. But John Deere Spreader Works has hit upon a delaying action that is doubling the life of their bottom boards and saving $4100 a year. The technique is simple—just paint the boards with water glass and sprinkle with silica sand.

by George H. Seaberg

Put a coating of water glass and silica sand on the bottom boards in your foundry and you can at least double their life. As a result of this inexpensive bottom board treatment the John Deere Spreader Works foundry of East Moline, Ill., recently realized an annual savings of about $4100.

The coating used is made up of No. 67 white silica sand and water glass. This coating can withstand a temperature of 3000 F before decomposing.

Two methods

Two methods have been used to apply the sand-water glass coating to bottom boards. The first method used was to apply one full strength coat of water glass and then to sprinkle sand on top of the water glass. In the second method water glass was diluted by 50 per cent with water. Then one coat of dilute water glass was put on the bottom boards and allowed to dry (Fig. 1). After the bottom boards were dry a second coat was applied. Before the second coat was allowed to dry, silica sand was sprinkled over it (Fig. 2).

The second method of coating the bottom boards was better for several reasons. When the full strength solution was used the water glass did not penetrate the wood adequately. Also, the sand did not stick to the board because the wood was too dry. Consequently the sand would fall off the boards during transportation from the preparation room to the foundry.

In the second method the first coat penetrated the wood satisfactorily and acted as a sealer. Then the second coat was not absorbed into the wood so fast, enabling the water glass to perform as an adhesive between the sand and the bottom boards.

Other methods of prolonging the life of bottom boards have been tried at the John Deere Spreader Works. These methods include: using an asbestos layer on bottom boards; utilizing a wood treatment; and trying several different types of wood. But none worked so well as the sand-water glass coating.

The November, 1956, issue of Modern Castings reported that Texas Foundries, Inc. of Lufkin, Texas, tried covering its bottom boards with several coatings of full strength high-silica ratio water glass. Their bottom boards lasted just as long as two coatings of dilute water glass and sand. But the Texas company incurred more material costs because the water glass used per board is twice as expensive as the silica sand used per board.

Pour 5500 molds daily

The John Deere Spreader Works employs twenty-two molders who average 250 molds per man per day. Some of the molds setting on treated bottom boards appear in Fig. 4.

Fig. 1 . . . First step in the John Deere method is the application of water glass diluted by 50 per cent with water. Then one coat of dilute water glass is put on bottom boards.

Fig. 2 . . . After the initial application, the bottom boards are dried. A second coat of water glass is applied as well as sprinkling a coat of silica sand.

Fig. 3 . . . Treated bottom boards utilizing the water glass and silica sand treatment are able to withstand temperatures up to 3000 F before decomposing.

Fig. 4 . . . Technique has doubled life of bottom boards since the first coat penetrates and acts as a sealer and the water glass as an adhesive between the sand and board.

Iron goes into the molds at 2400-2500 F. Pour-off men are on an incentive pay system, but there is no more than an average amount of spillage.

The weight of the castings that are on the 12x18x 1-3/8-in. bottom boards averages twelve pounds. The thickness of the sand mold between the casting and the bottom board is 1-1/2 in.

Castings stay in the molds between five and ten minutes. After molds are dumped bottom boards are given a normal amount of care. Boards are stacked and then wheeled in a barrow back to the molders. The sand-water glass coating is sufficiently tenacious to stay on the boards during this handling.

Statistics were kept on the life of bottom boards at the Spreader Works. It was found that with one application of the sand-water glass mixture the life of the bottom boards increased from three months to six months. And it is very probable that if the boards were coated periodically during their use they would last more than twice as long as uncoated boards.

Fig. 1 . . . In the center of this electron micrograph you can see the intersection of three ferrite grains—3200X.

Fig. 2 . . . At 3200X magnification a graphite nodule in malleable iron is far from having a homogenous structure.

EXPLORING TOMORROW

Magnified 12,500 Times!

The electron microscope has added new dimensions to magnification. These micrographs open the door to revising current concepts of malleable iron microstructure. Better explanations of graphitization and grain growth may be forthcoming. The material for this story was provided by Donald A. Pearson, Assistant Research Engineer, Link Belt Co., Indianapolis.

Fig. 3 . . . Here's how the upper right hand corner of the nodule in Fig. 2 looks when blown up to 12,500X magnification.

Fig. 4 . . . The carbide lamellae have a symmetrical parallel pattern in pearlitic malleable at 3200X.

MOST FOUNDRYMEN are familiar with the appearance of malleable iron when viewed under the optical microscope at 100, 250, and 1000 diameter magnifications. Now for the first time you can see what malleable iron looks like at 3200 X and 12,500 X. A whole new world of conceptions has been opened by the electron microscope which can achieve magnifications up to 50,000 because it uses electron beams with wavelengths much shorter than any light waves.

The electron micrographs shown here were produced by the carbon replica technique. Figure 1 shows at 3200 X the intersection of three ferrite grains in a standard malleable iron (grade 35018). In Fig. 2 you see what a graphite nodule looks like at 3200 X. Then in Fig. 3 the upper right portion of the graphite nodule is blown up to 12,500 X. A ferrite boundary leads off from the nodule and runs up into the right hand corner.

The symmetrical formation and arrangement of the carbides in pearlitic malleable are visible at 3200 X in Fig. 4. Figure 5 shows a pearlite and graphite nodule at 3200 X in the same sample. Note the lamellar pearlitic structure on right side of nodule.

The replicas and electron micrographs were processed by R. Kern, research engineer, Link-Belt Research Laboratory. These highly magnified structures of malleable iron were prepared for a high temperature stress-rupture research program sponsored by the Malleable Founders' Society.

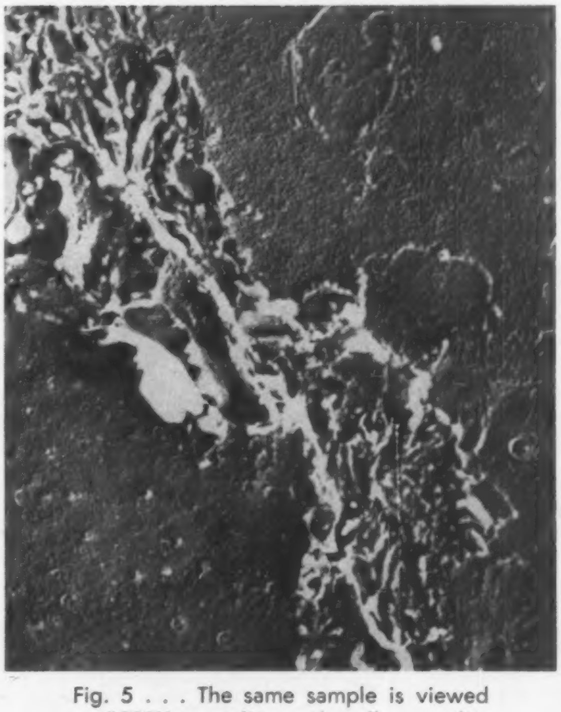


Fig. 5 . . . The same sample is viewed at 3200X revealing a lamellar pearlite structure on right side of a nodule.

How to Make Money in the Foundry Business

Break-even charts show the way to profitable operation; serve as a guide to good plant management. No other single business report will better reflect the interplay of:

- *profit and performance of past years,*
- *sales volume and profits,*
- *operating costs and sales income,*
- *product mix and profit potential.*

They reflect the economy of an operation at any level of operating volume and for any period of the past, present, or future.

Here are 13 step-by-step diagrams which tell how to use break-even charts to assure your company's future.

by Roger B. Sinclair
Roger B. Sinclair Associates
Larchmont, N. Y.

An essential prerequisite for preparing break-even charts is the availability of reasonably detailed cost data. Without a break down of costs by type—fixed, variable and regulated, the preparation of a break-even chart would be impossible. However, most foundries maintain a natural separation of costs and expenses. So it is usually well within the scope of most foundries to develop a break-even chart without incurring a great amount of difficulty.

Break-even charts have many applications in all areas and at all levels of foundry management.

These charts determine the profit potential which should be realized at varying levels of production volume. They direct sales activities by illustrating the minimum departmental volume levels which must be attained before a profit is possible. They indicate the levels of fixed and variable costs at different sales volumes.

They measure over-all, as well as departmental efficiencies, indicate economies which must be made when volume falls off, and guide management and supervision in controlling labor and material costs at varying production levels.

In the evaluation of price adjustments, either upward to recover higher labor and material costs, or downward to meet excessive competition, the break-even chart will indicate very quickly the effect of such changes. What a price increase might do to the foundry's competitive standing, or the additional volume required to offset a price decrease, are determined very quickly and with a high degree of accuracy.

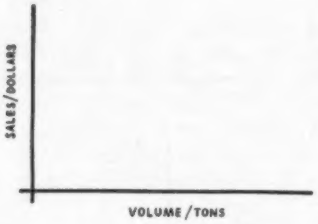
In justifying the purchase of new

equipment, or in the planning of methods changes, break-even charts will provide an actual dollar comparison for the specific operation under investigation, illustrating the economies and additional profits to be realized.

As a measure of efficiency, overall break-even charts are perhaps the best measure yet devised to appraise management's own ability to manage, i.e. to demonstrate the company's ability to operate profitably within its budget.

On the operational level, departmental break-evens indicate the ability of each supervisor to control costs in his department. With the aid of break-even information, he is in a position to adjust his direct and indirect costs in balance with careful check on all items of expense when falling volumes indicate that economies are necessary.

Figure 1



An analysis of operating costs, designed to separate expenses "by type" must precede the preparation of a break-even chart. Costs vary in their relationship to volume. Since the break-even chart relates cost-outgo to sales income, and determines the potential profit as a function of this relationship, this separation of operating expense must be completed before a chart can be drawn.

Briefly stated there are three types of costs in every operation:

1. Fixed costs, such as salaries, taxes, insurance, depreciation, interest on loans, etc., will remain constant regardless of business volume.

2. Regulated costs are of a constant nature, but their level will vary at the decision of management. Here are costs which can be adjusted at will, such as advertising, sales promotion, research.
3. Variable costs vary directly with sales volume and include such items as direct labor and materials, some indirect labor, part of the overhead expense.

For the preparation of a break-even chart, cost data should be selected to reflect periods when product mix and production volume were normal.

Step 1—Draw ordinates . . .

On a sheet of graph paper draw two ordinates (Fig. 1). The horizontal represents volume to about 150 per cent of normal; the vertical represents sales and operating dollars, again about 150 per cent of normal sales value.

Step 2—Fixed and regulated expenses . . .

Mark off the fixed and regulated expense levels, which we assume as constant, regardless of sales volume (Fig. 2).

At the level of normal business, mark off the point of variable costs. Connecting this point with the totals of fixed and regulated costs at zero volume produces a line which indicates the rise of variable costs at increasing volume.

Step 3—Sales line . . .

Finally, draw in the sales line (Fig. 3). Mark off the sales dollar total at normal volume of operations, connect this point with the intersection of the two ordinates. Now the break-even chart is complete. Where the two lines, that is the total cost line and the total sales line meet, lies the break-even point for the operation, under normal conditions and at normal volume.

Step 4—Interpreting break-even charts . . .

The first is the break-even point itself (Fig. 4). Its position in relation to volume indicates the inherent profitability of the foundry. Its relation to the cost and sales dollar scale indicates the cross-over point, where profits turn to losses due to low volume or high costs.

A high break-even point (low profit percentage at normal volume) may be the effect of a number of causes, the most frequent of which will be found in the following areas:

a. Low productivity through inefficient operations and antiquated methods. Poor individual output of productive men, high indirect labor requirements, and costly handling will show up in excessive variable costs.

b. Poor costing procedures, inadequate attention to departmental breakdown and overhead distribution, are frequent causes for a high break-even point. Blanket overhead rates may fail to re-

Figure 2

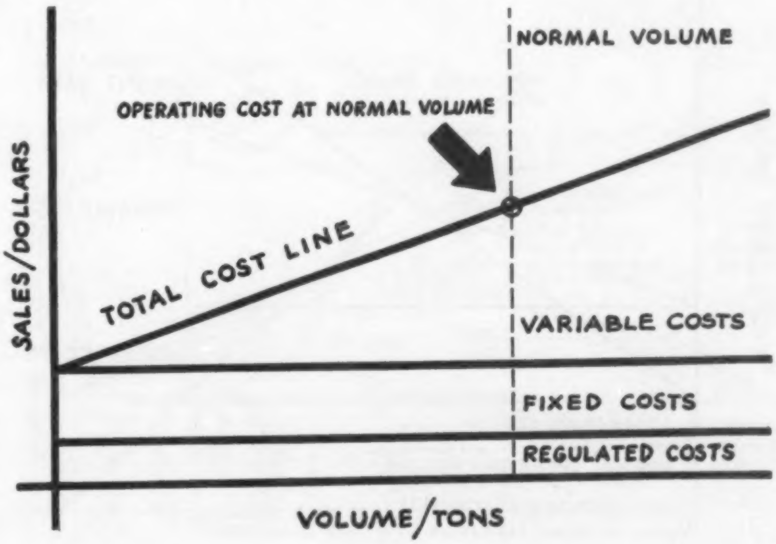
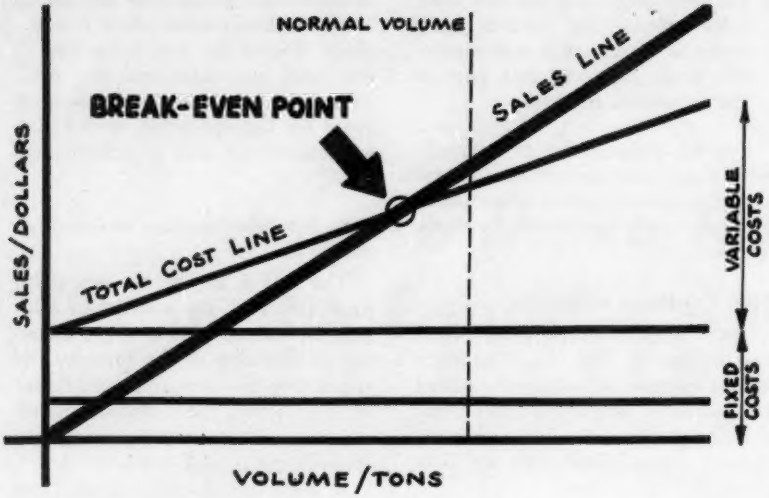


Figure 3



cover a department's full share of its costs.

One result is usually an increasing volume of business at a loss which reflects in the low sales dollar line of the break-even chart. This is typical of a foundry which is busier than ever.

c. Yet another cause of an unfavorable break-even position can be found in unbalanced sales. Minimum loading of all production section in the foundry is essential to ensure full absorption of overhead by all departments. Any unabsorbed burden due to low volume of operations in one section automatically increases the burden in other sections and decreases the competitiveness of the departments working normally. The minimum requirements for each department of a foundry can be readily obtained from a departmental break-even chart.

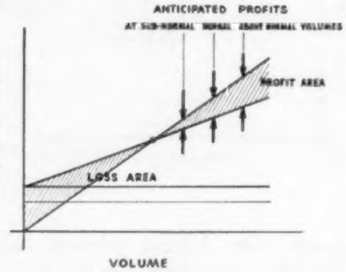
Step 5—Profit area . . .

The slope of the profit path (Fig. 5) is a valuable guide to management in the planning of operational improvements. It will indicate the normal return at normal volume levels, but also what profits should be produced at levels above or below that level.

During good business cycles, high volumes should produce extra high profits because profit pick-up after break-even increases sharply with volume. This is only too often overlooked by many foundries who never question the cost of operations when the business outlook is rosy. At the other end of the scale, the break-even point at low volume levels will tell us exactly to what point we must limit our regulated and variable costs to maintain even a reduced profit level.

The actual slope of the sales line above the cost line is therefore an indicator to the direction of future foundry planning. If the slope is gentle, it tells us that a reduc-

Figure 5



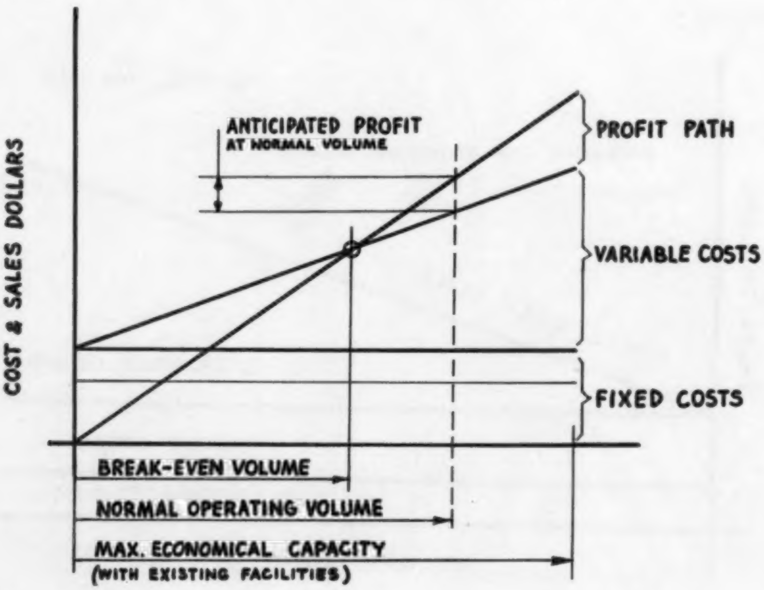
tion in direct costs will lower the break-even point and increase our profits much faster than the reduction of fixed costs. It indicates that it would be wise to spend more for fixed expenses, such as new machines and mechanization, rather than concentrate our efforts on reducing them.

If the slope of the line is steep, however, it indicates that our direct costs are already low. Our product could stand a reduction in selling price if market conditions should force us to take such a step. Little would be gained by more mechanization designed to reduce direct costs.

Step 6—Margin of safety . . .

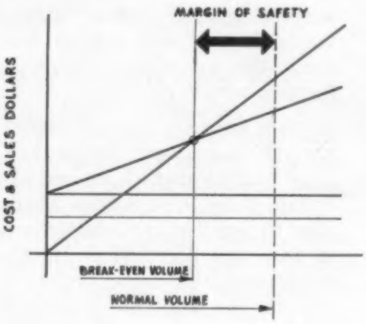
The distance of the break-even point from the normal output level in the volume scale of the chart

Figure 4



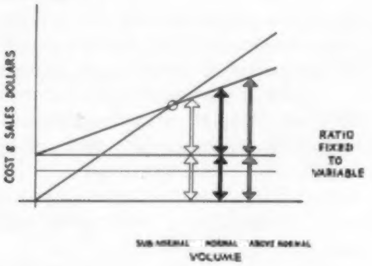
is yet another guide to management's actions (Fig. 6). This distance might be called the "safety margin of operation." If the break-even point lies close to the level of normal volume, trouble and losses are certain when volume falls

Figure 6



off or when production difficulties, such as excess scrap, occur. A small safety margin also indicates a weakness in operational management. Any foundry which can do no better than barely break even at normal volume, is not showing its ability to earn a reasonable return on the capital invested in its operation.

Figure 7



Step 7—Ratio of fixed to variable costs . . .

The relation of fixed and variable costs is another important guide in assessing the foundry's competitive standing (Fig. 7).

High fixed costs are often assumed to be the cause of unprofitable operations. A closer scrutiny, however, may indicate that fixed costs have to be raised in order to increase profits. Such would be the case in the installation of more up-to-date equipment and machinery or labor saving devices, which are bound to raise the level of fixed costs, but lower the variable costs sufficiently to effect an over-all reduction in operating costs.

The ratio of fixed to variable costs is a point of particular concern to captive foundries where fixed cost levels may be considerably higher due to the share of administrative overhead from the parent company. The break-even chart is a most valuable tool in this case to determine the share of overhead which the foundry can carry. This is particularly important if the captive foundry is also actively engaged in the sale of commercial castings and the maintenance of competitiveness becomes a necessity.

Step 8—Departmental evaluation

. . . The charts discussed to this point have covered complete operations and are often not detailed enough to reflect the cause of wide cost variations. To obtain such details, the effectiveness of the major production sections of the foundry should be measured.

A departmental break-even chart offers this information. Such a chart, applied to all mold producing sections of the foundry, is a composite of the department's operating costs plus the share of operating costs from other departments which supply the section with service.

Figure 8 illustrates a typical composite chart for a molding department. The chart shows fixed, variable, and the sales value from that department. It also includes a share of fixed and variable costs of other sections which supply service (or dollars) to the department in question. As shown in Fig. 8, the break-even chart for this molding department includes a share of the coreroom costs, a share of cleaning room costs, a share of melt and metal costs, and a share of general foundry overhead.

A composite break-even chart produces a complete picture of the profitability of one foundry department, set up as if it were an independent operation. It determines what the section should contribute to the total profit picture of the foundry and what its share of operating costs and expenses should be at all levels of business activity. This is the chart which provides a forecast and guide for the departmental supervisor in maintaining a profitable operation in his section.

Step 9—Planning mechanization

. . . Break-even charts also find widespread application in the justification of equipment purchases and in determining economical degrees of mechanization.

The right degree of mechanization will tend to lower the break-even point through reductions in variable costs, in spite of an increase in fixed costs. Big investments for mechanical equipment, however, will invariably increase the foundry's capacity and can pay off only if an adequate volume of

Figure 8

COMPOSITE BREAK-EVEN CHART

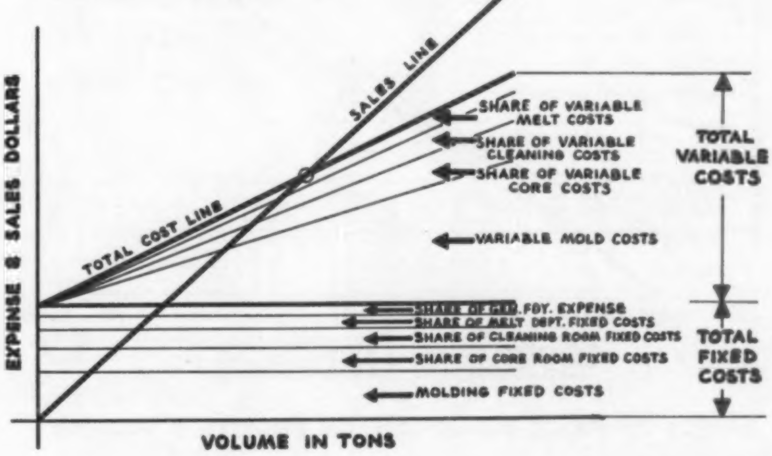


Figure 9

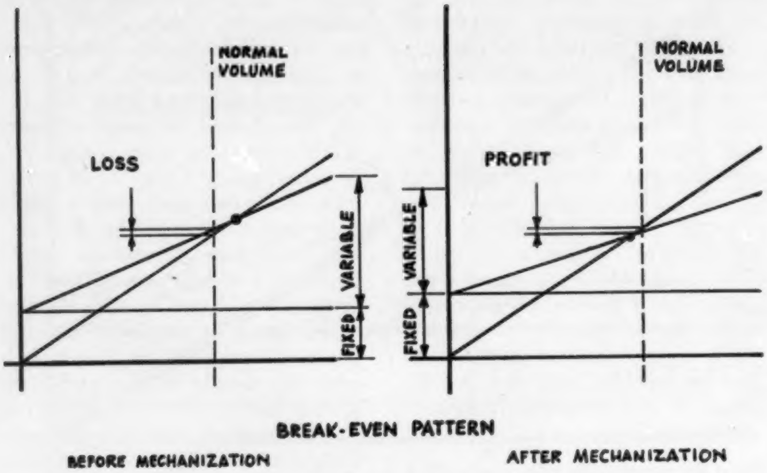


Figure 10

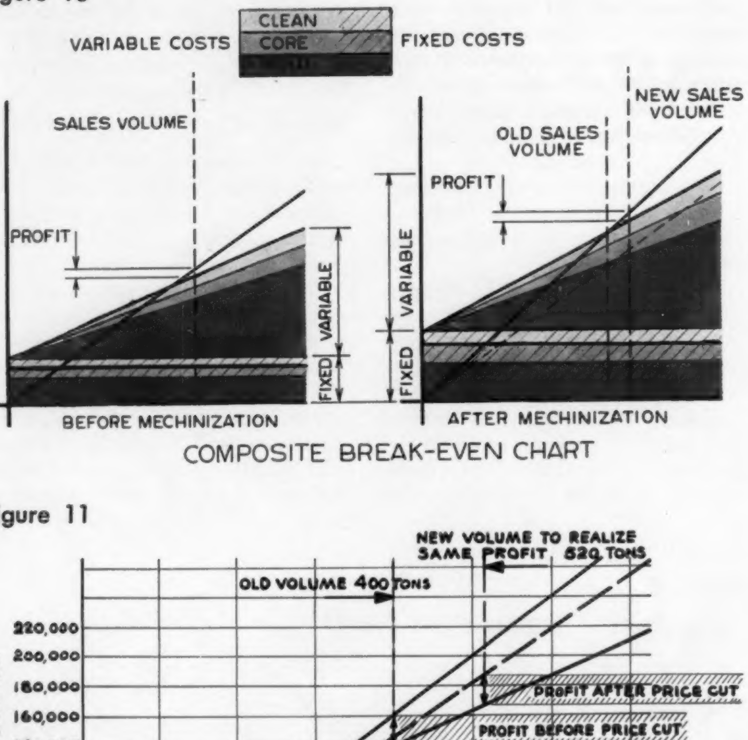
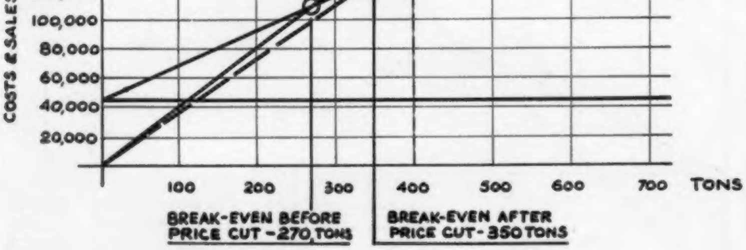


Figure 11



EFFECT OF PRICE REDUCTION ON PROFITS & VOLUME

new business can be found to balance the new "normal capacity."

To find the right balance between obtainable volume and justifiable mechanization, two points require careful study:

1. Will the increase in fixed costs be offset by a decrease in variable? If it does not, a loss will be incurred. If it is even, nothing has been gained. If it is greater, mechanization will pay off, because the necessary volume is there to sustain it.
2. What is the new capacity under normal operations? Is there a large enough market and an adequate sales organization available to get the necessary share of such a market. If it is not, strengthen the sales organization in line with the plans for mechanization, or leave the project alone.

Here are two typical case histories:

The first deals with a molding operation which could not be run profitably at normal volume of business. There was no chance to increase the volume of production. The problem was to determine whether a moderate mechanization project would bring the department out of the red.

Figure 9 (left) illustrates the operation before mechanization. At normal volume, total costs exceeded the value of total sales. Figure 9 (right) shows the projected break-even chart after mechanization. While substantially increasing fixed costs, variable costs could be reduced by labor savings to a point which resulted in a lower total cost line.

Although the volume of production did not change, the value of sales now exceeded total costs of operations. In this case, mechanization plans did pay off.

The second case history illustrates a different problem. Here it was planned to increase the production from a profitably operating department through mechanization. A composite break-even chart was used to determine what additional volume of business would be needed to offset the increased fixed costs and justify considerable capital expenditures.

Figure 10 (left) illustrates the operation before mechanization and

the level of profit obtained. Figure 10 (right) showed the increased costs of the revised operation which indicated a rise in fixed and variable costs due to a greater share of core, clean, melt, and other operations necessary to sustain increased mold production. An increase of 12 per cent in sales would be required to secure the same level of profits previously obtained.

Step 10—Price changes . . .

Another application of break-even charts is particularly timely today. When competition is severe, there is a strong tendency among many foundries to reduce prices to a level which will barely return the cost of manufacture. The reasons are usually lack of cost knowledge or the desire to absorb more overhead by increased volume. However, the latter is true only under certain conditions.

Lower prices mean a lower sales line on the break-even chart. This raises the break-even point, reduces the margin of safety and naturally reduces the profit potential. Figure 11 illustrates the effect of a 10 per cent planned price reduction in a small jobbing foundry. The break-even point was at 270 tons. A 12-½ per cent profit was realized at a monthly volume of 400 tons. To meet strong competitive pressure, a break-even chart was used to study the effect of a 10 per cent price reduction.

At the new price level, the break-even point was raised to 350 tons and the old profit could be realized only if a 520 ton volume could be secured.

In any program of planned price reduction, the changes can be justified only if enough new business is obtained. Not only must it compensate for the rise in the break-even point, but also justify itself by enough new sales to produce additional profits.

Step 11—Predicting the future

Illustration 12 came from a steel foundry which planned to spend considerable money on an extended program of modernization. Conclusive proof was required by management to obtain approval for capital expenditures. In spite of the substantial increase in fixed and regulated costs—depreciation, taxes, insurance, etc., the projected savings in labor and overhead, plus the considerable faster profit pick-up even at reduced sales levels, convinced the board of directors to approve the program. While this program is not entirely completed, the forecast illustrated by the break even chart is proving itself to be substantially correct.

Illustration 13 is drawn up to compare the operations in one foundry production area with another. Departmental costs, quantities, production time, etc., affect the cost of manufacturing and therefore the final choice of a production center. This information is easily put together to provide the answer quickly and clearly in a break even Chart.

Management needs break-even charts to correctly appraise conditions of operations and form the basis for profitable decisions. In today's highly competitive markets, this form of guidance and direction is of ever increasing importance.

Figure 12

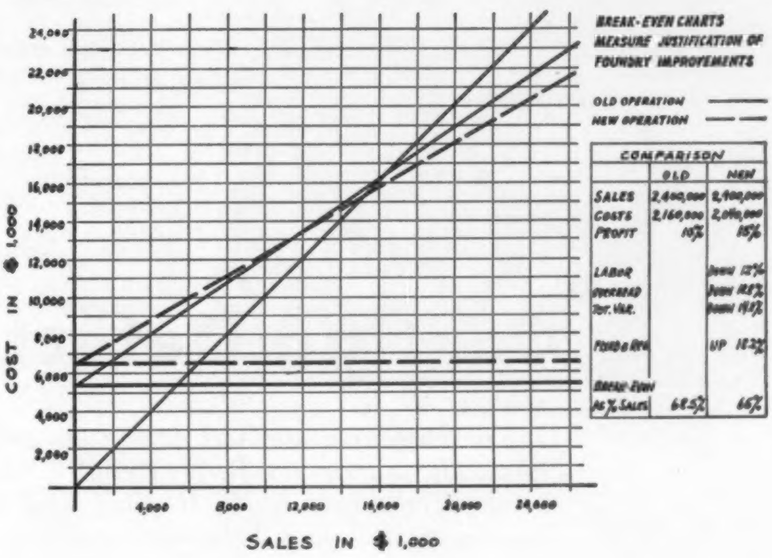
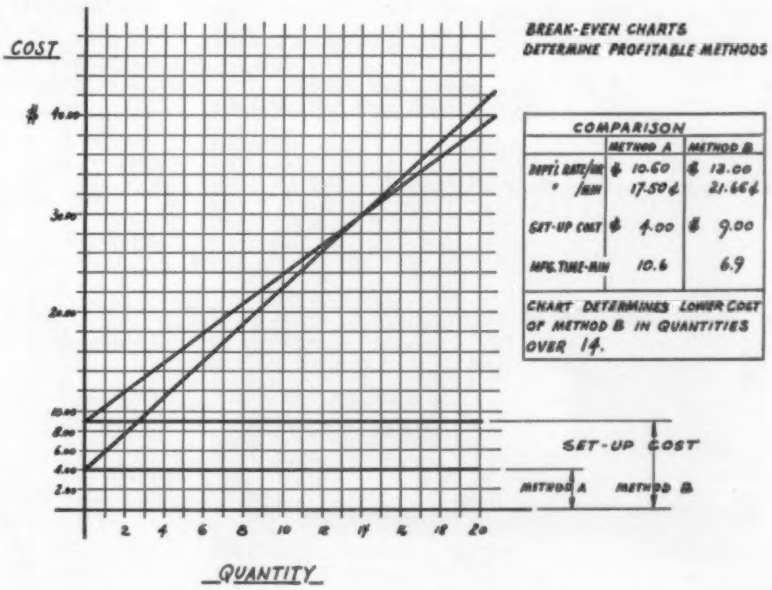


Figure 13



Casting Defects . . .

This is the fourth and last article on green sand principles. The authors are R. W. Heine, University of Wisconsin, Madison, Wis.; E. H. King, Hill & Griffith Co., Cincinnati; and J. S. Schumacher, Hill & Griffith. The three preceeding articles discussed clay-sand-water, additives, and molding.

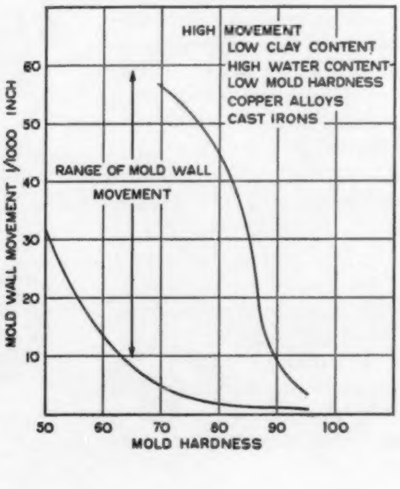
THE ENGINEERING PRINCIPLES of green molding sands should be well-known by foundrymen who seek to control the quality of castings produced in green sand molds. A common casting quality problem is the one shown in Fig. 1. Of the two castings shown, the one on the right was made of gray iron poured into a green sand mold rammed to 55 mold hardness[1], while the one on the left was poured of the same iron in a mold made from the same sand rammed to 90 mold hardness.

Low mold hardness results in a dimensionally oversize, very rough casting. The casting is actually larger than the pattern. On the other hand, the harder mold produced a dimensionally accurate casting showing normal patternmaker's shrinkage and a smooth finish characteristic of the fineness of the sand. Not obvious in Fig. 1 is the fact that the measured specific gravity of iron in the swollen casting is about 7 per cent lower than that of the dimensionally accurate casting due to microvoids generated in the casting as it swells.

Improvement in other metal shaping processes requires that dimensional variation in castings be reduced to a minimum. What can be done in terms of green sand formulation and molding practice to achieve dimensional precision in green sand casting? The answer lies in making molds rammed to high enough bulk density in properly formulated sands so that adequate green and dry strength are developed

Fig. 1 . . . Left casting has mold hardness of 90; on right, 55.

Fig. 2 . . . Range between curves reflects dimensional variation.



commensurate with casting size. Low sand density, strength, and mold hardness are the prime reasons for over-sized and dimensionally variable castings. Low density of sand in the mold permits mold wall movement to occur when the metallostatic pressure of the casting is exerted during and after pouring.

A summary of some factors effecting mold wall movement is presented in Fig. 2 (reference 10). This figure summarizes the range of results for a number of variables such as clay content, moisture, density, mold hardness, metal, etc. studied in a specific casting. Mold wall movement in Fig. 2 refers to the movement of a mold cavity surface as reflected by variations in the dimensions of the casting compared with the pattern and deducting shrinkage[10]. The upper curve in Fig. 2 refers to the maximum and the lower curve to the minimum limits of mold wall movement observed. Thus the range between the two curves reflects the dimensional variation which may occur from all causes. Figure 2 reveals the dominant effect of the bulk density and mold hardness to which the mold is rammed. At low density and hardness, the total and the range of dimensional variation is large; i.e. swelling can occur readily. At high density and mold hardness, the total and the range of dimensional variation is small so precision can be achieved.

Figure 2 refers specifically to southern bentonite bonded sand and shows a minimum mold wall movement of 0.002 to 0.005 inches. Western bentonite and fire clay bonded sands show mold wall movement minima of 0.010 to 0.020 inches and 0.020 to 0.030 inches, respectively. Similar observations have been reported by a number of authors[13,14]. Figure 2 also demonstrates that higher clay content and lower moisture content reduces the total amount and vice versa. Thus, in sand formulation, those principles aimed at a clay-saturated sand practice of the proper moisture content favor casting dimension control. However, the importance of ramming to adequate density must never be overlooked.

Metal Porosity or Unsoundness

When a casting is as badly swollen as that in Fig. 1, it is generally unsound. In this specific case, the increase in volume of the swollen casting was 23 per cent but the increase in weight was only 14.1 per cent. The difference is attributable to internal microvoids. The amount of oversize dimension which will produce microvoids is not known. A casting with microvoids should always be dimensionally compared with the pattern from which it was made to determine whether mold wall movement may be the cause of the porosity.

Expansion Defects

Buckles, rat tails, and scabs are defects associated with disruption of the mold cavity surface due to expansion of the sand. From the viewpoint of sand formulation the simplest means of eliminating expansion defects is by using an adequate percentage of clay in the molding sand. Freedom from expansion type defects is one of the advantages of clay-saturated molding sands. The expansion defect shown in Fig. 3 is typical of that occurring in a sand containing too little clay. This type of defect can be eliminated by making a substantial addition of new clay when the sand is mixed for use. Cellulose additives may also be used for this purpose. However they are not as effective as clay.

Fig. 3 . . . Typical expansion defect due to insufficient clay.

Dirty Castings

Sand may appear on cope or drag surfaces of castings and the defect may be classified as "dirty casting". This dirt may be the result of mold erosion by the metal, loose sand grains from over-dry sand, a poor base sand particle size distribution, or simply unclean molding practices. With respect to sand formulation, it is necessary to develop adequate dry strength to prevent dirt. The proper use of moisture in either clay-saturated or unsaturated sands is necessary to achieve this dry strength. The importance of ramming in relation to dry strength must not be overlooked as stated earlier.

An inadequate clay content is another cause of dirty castings. This is especially true if a sand contains an excess of carbonaceous matter in relation to the clay present. The carbonaceous matter can burn out during pouring. The sand mass then loses strength permitting sand grains to be washed into the metal stream.

Pinholes or Gas Defects

Moisture ceases to be a problem in gas defects when the sand contains 10 to 30 per cent free water above the calculated absorbed water value. This statement assumes that the principles regarding a proper use of base sand, clay, and additive are being followed as discussed earlier. Any condition such as balling of fines or clay which prevents uniform distribution of the water must be avoided. Also, a clean sand must be maintained. When these principles are followed, no gas type defects attributable to the sand should occur.

General Level of Defects

The defects listed above together with other minor problems such as surface finish are all influenced in amount and severity by two important sand conditions—cleanliness and temperature. From thermal effects and reactions with the metal, the sand becomes

Table 1 — Summary of Synthetic Sand Practices for Medium Weight Castings

Clay-Sand Type	Saturated	Sub-Saturated	Unsaturated	
Clay	Bentonite	Bentonite	W. Bentonite	Fireclay
Base Sand	60 — 70 AFS, 4 screen	60 — 70 AFS, 4 screen	50 — 70 AFS, 3 to 4 screen	55 — 65 AFS, 4 screen
AFS Clay, %	9 — 14	7 — 10	3 — 6	11 — 16
True Clay, %	8 — 12	6 — 8	3 — 5	10 — 14
% H_2O, free	+20	+30 to 50	+50 to 100	+50 to 100
Green Comp. Str., psi.	14 — 20.0	10 — 14.0	5 — 9.0	6 — 10.0
Green Shear Str., psi.	4 — 6.0	3.0 — 4.0	1.5 — 2.5	2.0 — 3.0
Ave. Mold Hardness	84 — 90	82 — 88	74 — 86	76 — 86
Dry Comp. Str, psi W. Bent. Bonded S. Bent. Bonded Fire Clay Bonded	 Usually > 100 40 — 80 ——	 > 100 40 — 80 ——	 > 80 —— ——	 —— —— 60 — 80
Bulk Density, lbs. cu. ft.; Freshly Riddled Fully Rammed	 50 — 65 100 — 110	 45 — 60 100 — 110	 40 — 55 100 — 110	 50 — 65 110 — 120
Deformation, inches	0.010 — 0.020	0.020 — 0.030	0.025 — 0.040	0.020 — 0.035
Total Comp.% Iron Copper-Base Al-Base	 5 — 10 2 — 6.0 1.5 — 2.5	 5 — 10 2 — 6.0 1.5 — 2.5	 ——— ——— ———	 6 — 12
Special Additive	Cellulose	Cellulose	Cellulose	Cereal or Dextrin

progressively contaminated with silicates and deteriorated clay. This increases the incidence of expansion, dirt, and gas type defects. The current remedy consists of replacing the used sand with new sand at the rate of about 3 to 5 per cent per cycle of use. New sand may enter the system in cores or as a new sand addition. Clay and additives must be added to bond the new sand. The new sand plus good housekeeping can maintain a satisfactory level of cleanliness in the system.

Hot sand results from rapid re-use of molding sand in systems where there is insufficient time for cooling. The mixing of hot sands generally is inadequate and poor properties are developed.[11] Together with the problem of retaining moisture in the sand for molding, these effects cause an increase in the incidence of expansion, dirt and gas-type defects. Cooling of the sand remedies this problem.

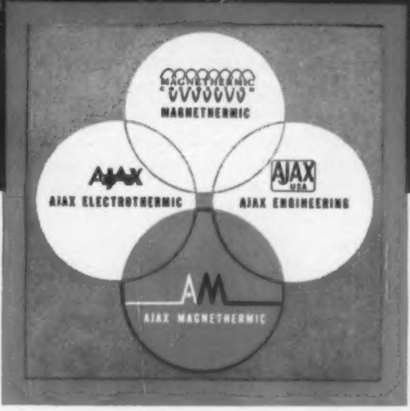
SUMMARY

Principles of green sand practices with clay-saturated and unsaturated sands are summarized in Table 1. The properties listed in Table 1 are the inevitable consequence of adequate mixing of the sand ingredients. These properties serve to describe a properly formulated sand. With the use of such sands and observance of the principles, defects attributable to molding sands can be reduced to a negligible minimum and casting dimensions can be controlled. The above statements however can only be made if the sand is molded to uniformly high density, strength, and mold hardness.

References

1. Foundry Sand Handbook, American Foundrymen's Society, 1952, p 96.
10. Heine, R. W., King, E. H. and Schumacher, J. S., *Sand Movement and Compaction in Green Sand Molding*, American Foundrymen's Society Preprint 59-32, 1959.
11. Heine, R. W., *Molding Sands, Molding Methods and Casting Dimensions*, Transactions, American Foundrymen's Society, v 64, 1956, p 398.
13. Sigerfoos, C. C. and Womochel, H., *Influence of the Mold on Shrinkage in Ferrous Castings*, Transactions, American Foundrymen's Society, v 48, 1940, p 591.
14. Sanders, C. A. and Sigerfoos, C. C., *Gray Iron Shrinkage Related to Molding Sand Conditions*, American Foundryman, v 18, Feb. 1951, p 49.

These twin 1000-lb. melting furnaces prepare copper for metal powder at the St. John's, Michigan, plant of Federal-Mogul-Bower Bearings, Inc.



WATCH AM

FOR THE NEW IDEAS IN HEATING AND MELTING BY INDUCTION

Copper Melting Furnaces, one of many products of AM, for the heating or melting of metals by Induction.

"induction heating is our only business"

Ajax Magnethermic CORPORATION

GENERAL OFFICES
P. O. BOX 839
Youngstown 1, Ohio

TRENTON DIVISION
930 Lower Ferry Road
Trenton 5, New Jersey

YOUNGSTOWN DIVISION
3990 Simon Road
Youngstown 1, Ohio

Circle No. 140, Page 139

S. C. Massari

Castings Congress Papers

This month Modern Castings previews eight important Castings Congress papers on a variety of subjects—titanium casting, high strength steel castings, dust collectors, oxygen-gas burner for arc-furnace melting, gap formation in permanent mold casting, heat treating cast iron, resin-bonded cores for steel castings, and a new high-silicon aluminum alloy.

TECHNICAL HIGHLIGHTS

Making Sound Titanium Castings ....p 51
Gas and shrink porosity is best eliminated through application of centrifugal force during casting. Bottom gating is recommended for both static and centrifugal casting. Molds of rammed graphite and shell cores of graphite, resin and pitch are giving better quality castings than machined graphite molds.

Grain Structure and Microporosity in Steel . . . p 61
Steep thermal gradients during solidification are a must for eliminating microporostity in high strength steel. When metal is extremely sound, high purity A.I.S.I. 4340 steel castings can be produced with up to 40 per cent reduction in area and 250,000-300,000 psi tensile strength. These properties approach and even exceed the high strength to weight ratios of the best forged aluminum and magnesium shapes.

Dust Collector Review ....p 75
Here's a practical guide to help you select the proper type of dust collector suited to your foundry needs. A table lists cost, smallest particle size collected, pressure drop, and power requirements for the six general types—settling chambers, inertial separators, cyclones, filters, electrical precipitators, and scrubbers.

Oxygen-Gas Burner for Arc Furnace Meltdown . . . p 84
An oxygen-gas burner is used to assist meltdown of scrap. As a result, electric power consumption was reduced 15 per cent, tap to tap time was reduced 15 per cent, and production increased 15 to 20 pounds per minute. Process can be used to increase production, aid on undersized transformer, and eliminate excessive overtime.

Gap Formation in Permanent Mold Casting . . . p 87
Cooling rate of casting in a permanent mold is markedly influenced by the formation of an insulating air gap between mold face and outer skin of casting. Then heat flows by radiation rather than conduction (which is faster). Cast metal structure and feeding patterns are altered in the areas where air gap forms. A complete background on this subject is presented in this extensive survey of existing literature.

Cast Iron Heat Treatment ....p 94
A complete detailed description of all heat treating practices for gray and ductile iron at Lynchburg Foundry Co. describes stress relieving, annealing, normalizing, quenching, and tempering.

Phenolic Resin Bond Cores for Steel Castings . . . p 101
This paper is a complete primer on fundamentals involving the use of phenolic resins in solid sand cores. Twelve tried and proven core mixes for a variety of steel casting needs are presented.

New High Silicon Aluminum Alloy ....p 111
This new alloy, X392, appears suited for die or permanent mold cast cylinder liners and blocks, brake drums, clutch plates, sheaves, and pulleys. Phosphorous is used to refine the massive primary silicon crystals which have previously hindered machinability of this alloy.

The AFS Castings Congress papers are the most authoritative technical information available to the metalcasting industry. Over 100 papers were prepared by close to 250 authors and presented at the 1960 Congress in Philadelphia, May 9-13. Papers receive preview publication in Modern Castings and then are bound into the annual volume of AFS Transactions for permanent reference. All papers have been approved by the appropriate Program and Papers Committee of the sponsoring AFS Technical Division. They are then edited by AFS staff members C. R. McNeill and M. C. Hansen.

Written discussion of these papers is welcomed and will be included in the publication of the 1960 bound volume of AFS Transactions. Discussions should be submitted by Aug. 1 to Technical Director, American Foundrymen's Society, Golf and Wolf Roads, Des Plaines, Ill.

FACTORS CONTRIBUTING TO SOUNDNESS OF TITANIUM CASTINGS

by J. W. Smith and T. A. Hamm

ABSTRACT

Internal and surface defects in titanium castings have been identified, and ways of overcoming these problems have been outlined. Results of this work indicate that titanium castings can be produced to consistently high quality levels when design, gating, pouring and mold requirements are met.

INTRODUCTION

The availability of an expendable graphite mold[5] has contributed a great deal to the development of many new possibilities in the casting of titanium shapes. The complex designs which may now be cast are presenting a host of problems which require answers. Among these problems are shrinkage, gas porosity, feeding distance, riser requirements, gating techniques and the need to make the expendable molds even more versatile than they are at present.

Other problems of alloying, melting and heat treating are equally demanding, but the solution of the aforementioned problems is required in order that these alloys may be put into usable cast shapes. The following work has been conducted in an effort to establish and identify the surface and internal defects, and to outline the conditions which must be met if sound titanium castings are to be obtained.

SHRINKAGE

Centerline shrinkage is the most frequently observed problem in titanium castings. Shrinkage is observed in two distinct forms.[1] The first and most prevalent is a dispersed void, such as shown in Fig. 1, and will always be found at centerline of uniform thickness sections where insufficient thermal gradients exist to produce the necessary directional solidification. The second type of observed shrinkage appears as a concentrated void and will occur in any thermal center, as shown in Fig. 2.

Shrinkage has not been observed in either unalloyed titanium or in the commercial alloys such as 6Al-4V as a gradual change from solid to mushy condition, but rather it appears as distinct voids even in the areas of dispersion. This factor may frequently be used to advantage since heavy sections will freeze to complete soundness, except for a small void located precisely in the thermal center of the section.

In many designs this void removes readily during the subsequent machining operations. In other cases where complete soundness is required, and the section is accessible to a riser, the thermal center may be moved out into the riser.

GAS POROSITY

It is quite logical to assume that when a shrinkage condition exists some gas may be associated with this porosity.[1] The small amount of gas which may exist along with the shrinkage voids is not considered to be a problem, since when sufficiently steep thermal gradients are produced to remove the shrinkage the gas is also removed. Gas, such as shown in Fig. 3, will occur in positions in the casting not related to thermal centers, and will be found most frequently on the cope surfaces of the casting.

These gas inclusions are readily identified by their smooth spherical appearance and may vary in size from pin point diameters, barely discernable by x-ray, to large inclusions where severe gassing has occurred. Two primary sources produce this gassing. The first is the result of an incompletely fired expendable mold. The second may result from the decomposition of water absorbed in the molds during handling prior to casting.

A third possible source of gassing could be the melting stock. However, this seems unlikely since the material has been vacuum melted prior to the introduction into the mold cavity.

Methods of Controlling Gassing

There are several methods by which the gassing of castings may be controlled. Considered to be potentially an effective method is the vacuum firing of both expandable graphite and machined graphite molds prior to their introduction into the casting furnace. While this procedure has been reported, it is not yet definitely known that vacuum firing will be essential.

In the work reported here, all mold firing has been accomplished by packing the expendable graphite molds in steel or cast iron boxes and completely covering them with 4 in. of powdered graphite. The molds are air dried for 16 hr followed by oven drying at 200 F for 24 hr. The packed box and molds are then

J. W. SMITH is ass't. mgr. of Mfg., and T. A. HAMM is Proj. Eng. Oregon Met. Corp., Albany, Ore.

brought up to 1650 F and held at that temperature for a period of 3 hr.[2]

The box and molds are permitted to cool in the furnace to a temperature of about 1100 F then removed and molds are unpacked when they drop below 700 F. This procedure has appeared quite effective in producing a mold which will not subsequently gas the casting. The greatest difficulty experienced has been with moisture pickup in the mold during the period of time after the mold has been unpacked and while it is being assembled and gated for pouring.

When relative humidity exceeds 45 to 50 per cent, gassing difficulties are usually experienced with molds which have been allowed to remain in the atmosphere for a period of several hours. Since the mold assembly work must be accomplished after firing, it is considered advisable that the completed mold assemblies either be held in a controlled atmosphere for a sufficiently long time to assure an extremely low moisture level or, more efficiently, that the assemblies be held for shorter periods of time in holding ovens operating between 250 and 600 F with rapid transfer from the molding oven to the vacuum casting furnace to minimize any possibility of moisture pickup.

Outgassing Procedure

Since Aug. 1959, an outgassing procedure has been employed whereby the expendable molds are packed in graphite in iron boxes, fired at 1650 F for 4 hr at temperature, removed from the furnace at that temperature and placed in a vacuum chamber for outgassing until cool enough for unloading.[3] This procedure consistently produces a reduction in surface contamination. Castings are much brighter, although experience has been that the least surface reaction occurs in machined molds.

A final and extremely effective method of avoiding the gassing condition is the use of the centrifuge technique, as shown in Fig. 4. Forces up to 20 gs may be applied by spinning the casting around a horizontal or vertical axis. With this technique there is no gassing discernable by x-ray.

The development of a vertical axis centrifuge furnace utilizing the consumable arc skull melting tech-

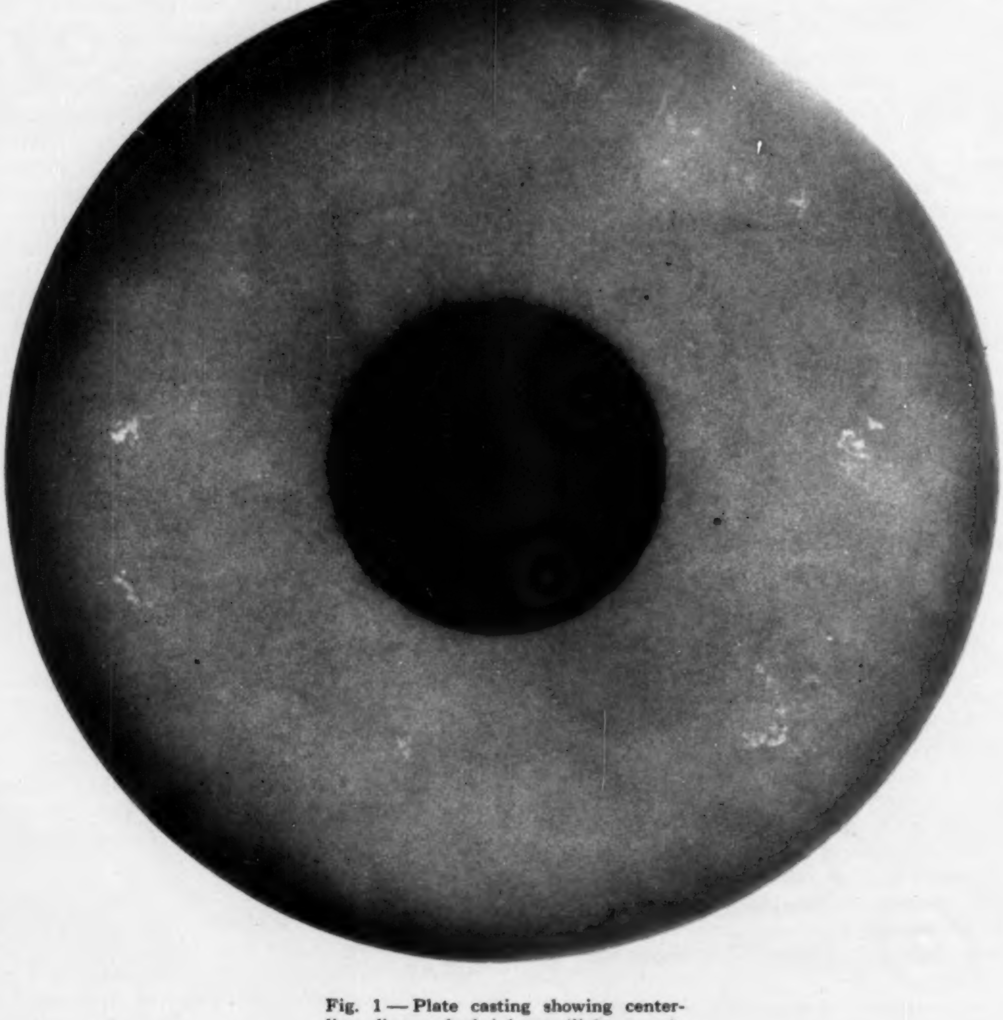


Fig. 1 — Plate casting showing centerline dispersed shrinkage (light areas).

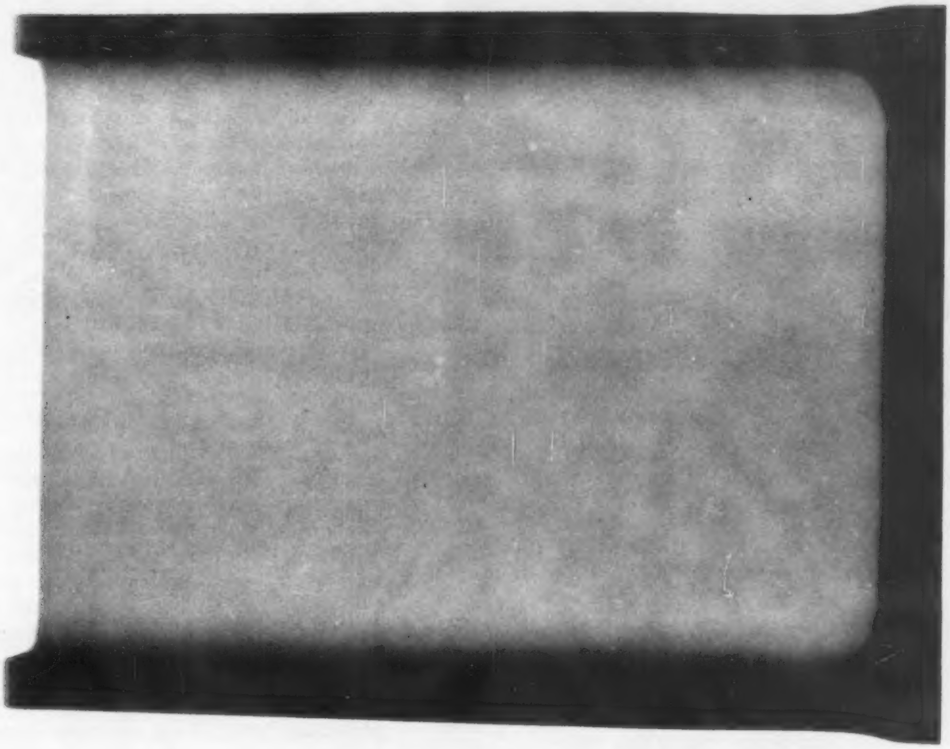


Fig. 3 — Casting showing random dispersion of gas porosity (light areas).

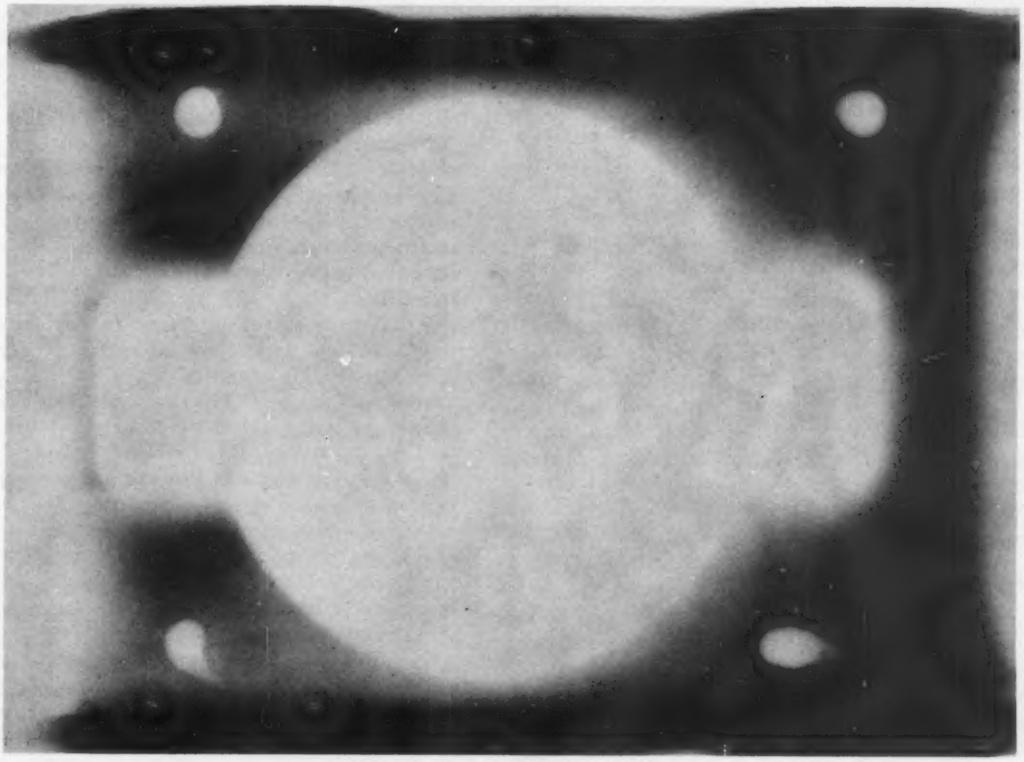


Fig. 2 — Casting showing concentrated shrinkage voids in thermal center.

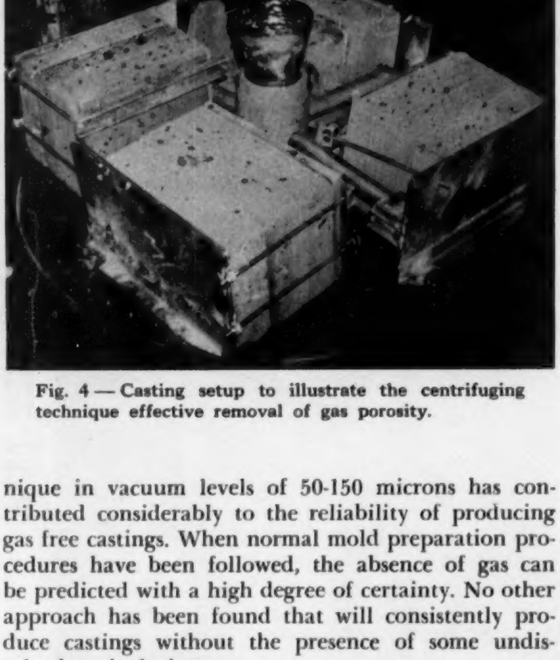


Fig. 4 — Casting setup to illustrate the centrifuging technique effective removal of gas porosity.

nique in vacuum levels of 50-150 microns has contributed considerably to the reliability of producing gas free castings. When normal mold preparation procedures have been followed, the absence of gas can be predicted with a high degree of certainty. No other approach has been found that will consistently produce castings without the presence of some undissolved gas inclusions.

FEEDING DISTANCE

The distance titanium will feed to complete the soundness during solidification is an extremely important consideration for a given set of conditions.[4] It is useful to know what the extent of the feeding is in uniform thickness sections combining both the edge effect of the casting and the sound distance beyond the riser. It is also useful to know the degrees of taper required for any shape with a given edge thickness which will feed to soundness over infinite distances.

These two facts may be determined readily for simple shapes for any condition where the metal temperature, mold material, mold temperature and alloy are controlled. When this type of information has been determined, it becomes useful for casting design, gating and risering and prediction of the internal quality level of the casting. Considerable work has been done to establish as nearly as possible the extent of feeding of titanium under various standard conditions.

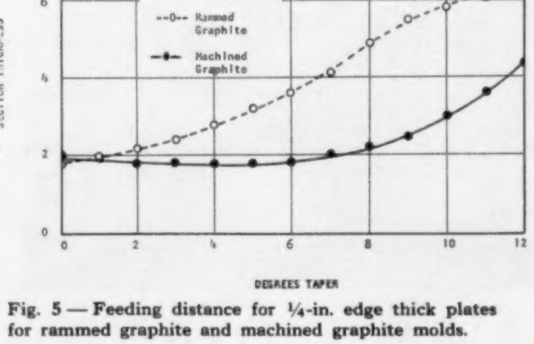


Fig. 5 — Feeding distance for ¼-in. edge thick plates for rammed graphite and machined graphite molds.

Since machined graphite molds and rammed graphite molds are the principal available materials in which to cast, most of the work thus far was done with these materials. The program was aimed at determining the total feeding distance combining the sound edge-effected area and the sound area surrounding the riser in uniform sections of varying thicknesses from ⅛-in. to one in. The program was also aimed at determining the degrees of taper required to produce complete soundness for varying edge thickness from ⅛ to one in.

The work was done primarily with plate sections in thicknesses to one in. and with 5 and 6 in. diameters. All molds were poured with the mold at room temperatures, and melting was done in a consumable electrode skull furnace. Work was also done with tapers to a maximum of 12 degrees with the various thickness plates. The total feeding distance was determined by measuring the least distance from the edge of the casting to the first porosity, the least distance from the riser perimeter to the first porosity and combining these two numbers.

Soundness Condition Change

The information gained from inspection of x-rayed plates was plotted on graphs to illustrate the change in the soundness condition with each additional increase in taper towards the riser. The method of determining soundness was to determine a *T* value, which was a number representing the ratio to distance sound and the section thickness (T = total sound + section thickness). The graphs are shown with the *T* values along the *Y* axis, and the taper of plates in degrees along the *X* axis.

Graphs illustrated show the increase in soundness of plates with edge thicknesses of ¼-, ½- and ¾-in. The graphs are also shown with two curves, representing the feeding distance in machined graphite and rammed graphite molds. Figures 5, 6 and 7 illustrate the feeding distance for ¼-, ½- and ¾-in. plates, respectively.

It has been shown in recent experimental castings that a straight taper from the edge of a section toward the feeding source is not effective in producing soundness. A more effective padding method has been to add a parabolic type of taper based on the feeding distance study findings. In one instance a shrinkage free part was cast using a progressive taper beginning at the end of the section with a 7 degree taper, and progressively decreasing the taper to 6, 2 and 0 degrees near the feeding source. The primary taper requirements were based on the soundness value necessary to feed a ¼-in. thick section.

A wave of solidification progresses rapidly in the graphite molds, and a greater degree of padding is necessary at points distant from the feeding source. The necessity for a greater degree of padding is shown by the low *T* values of feeding distance curves in the graphs.

No attempt has been made to determine actual

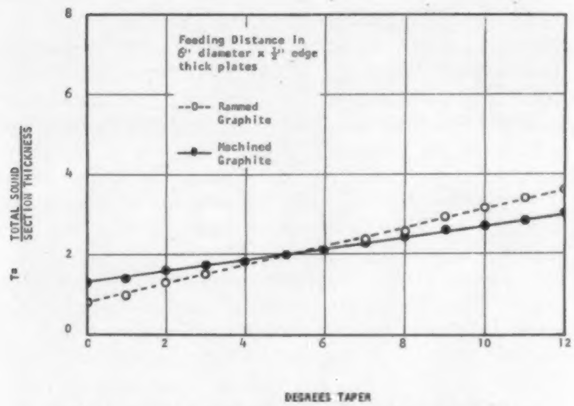


Fig. 6 — Feeding distance for ½-in. edge thick plates for rammed graphite and machined graphite molds.

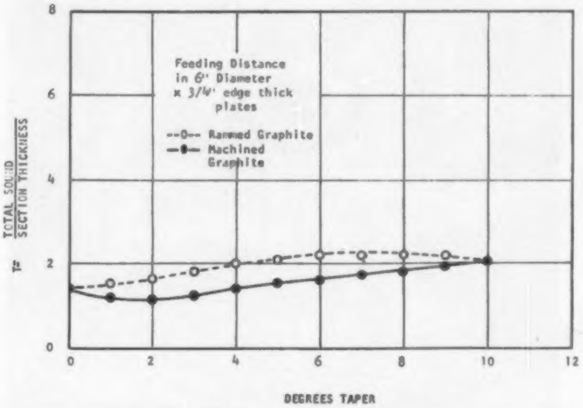


Fig. 7 — Feeding distance for ¾-in. edge thick plates for rammed graphite and machined graphite molds.

temperatures prevailing during the freezing cycle. The problem of temperature recording is quite complex, and sufficient time was not available for a more extensive program.

The general characteristics of padding castings to obtain a sound section shows that a parabolic type of taper will be more influential in obtaining greater feeding distances. A more extensive research program is necessary to definitely establish a correlation between soundness and the type of taper.

The feeding distance in the centrifugally cast parts is increased over the feeding distance in static cast parts. A direct comparison of increased feeding distance has not been established at the present time. Shapes that were formerly cast statically with dispersed shrinkage occurring in several areas can be cast to complete soundness centrifugally. The centrifugal method of casting permits more efficient use of risers and padded sections.

Molds to be cast centrifugally are positioned to take full advantage of forces exerted on the riser after pouring is complete and fluid flow stops. The molds are also positioned as far as practicable to gain the advantages of increased feeding distance that is a result of acceleration of the metal in the direction of rotations as the mold cavity is filled.

RISER REQUIREMENTS

Concentrated shrinkage of the second type described places a great deal of emphasis upon risers where it is essential that the shrinkage void be removed from the casting. Because of the extremely short feeding distances found in both machined and rammed graphite molds, the principle function of the riser is to feed the section of the casting directly beneath it.

It was found that the rapid chilling of castings in the machined graphite molds reduced the riser requirement to approximate diameters of twice the section thickness. These diameters were sufficient to cause the riser to remain molten sufficiently long to do the necessary feeding required in the casting, and to move the thermal center into the riser just above the casting surface. In all cases risers having heights equal to their diameters were adequate.

In the expendable graphite molds having increased feeding distances especially around the periphery of the riser, it was found that minimum riser diameters required were equal to 2½ times the section thickness at the point of riser connection. All efforts to use necked down risers have been unsuccessful because of the extremely rapid chilling effect of the mold material.

This requirement of full riser contact frequently makes attachment to the casting difficult with subsequent removal difficult both in terms of the economy of grinding the contact area, and also in re-establishing the dimensional tolerances of areas covered by the riser. When producing a casting to complete soundness every thermal center must be either risered or chilled rapidly enough for feeding through the adjoining thinner section.

Chilling is only moderately effective due to the high thermal conductivity of the mold. However, some use of copper chills and also machined graphite chills in the expendable graphite molds has assisted in promoting sufficiently steep thermal gradients to obtain soundness in isolated areas.

GATING

The basic gating requirements for titanium castings are not greatly different from other metals in other mold materials. The problem of pouring, however, is somewhat complicated because of the necessity of the gating system handling the entire melt in less than 5 sec. Initially, developed systems were based on the practice of pouring directly into the top of the mold cavity thus eliminating the gating system as such, and with the flow channels becoming the riser.

This method was even less successful for titanium than it might be for standard gating in usual foundry practice. While there was no slag problem, the metal would enter the mold cavity with severe turbulence, and would produce a condition which came to be known as surface laps which were not deep in many cases. This would ruin the desired surface finish of the casting. It was soon learned that bottom gating techniques would be required to produce satisfactory surface appearance on the casting.

Fig. 8 — Mold setup to show method of stacking molds for vertical gating technique.

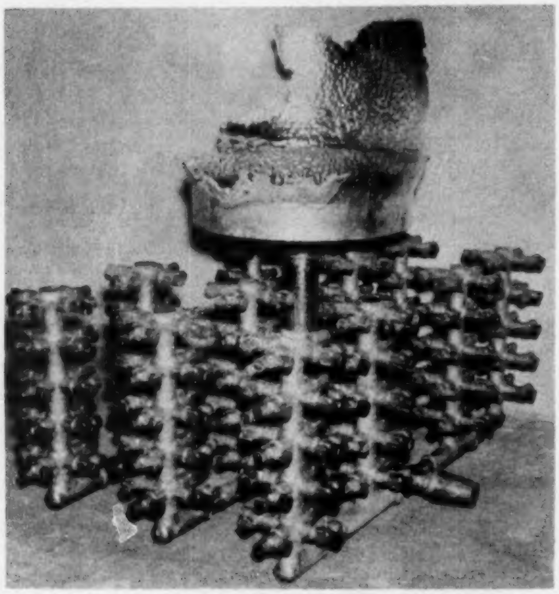


Fig. 8a — Casting setup with graphite mold material removed to show bottom feed, vertical gating technique.

Side Gating

It was also found that in certain designs gating could be accomplished from the sides of the casting, providing the metal did not drop more than one or 2 in. into lower sections of the mold cavity. It is considered that the techniques of gating as described in the work reported by Battelle on *Fluid Flow in Transparent Molds,*[7] especially with reference to the work done with vertical gating, resulted in the most satisfactory filling of the mold cavity and produced the best appearance on the surface of the casting.

The duplication of this work on a commercial basis has been somewhat limited, due to the need for fairly elaborate piping systems of graphite tubing for distribution of metal to all the molds requiring pouring in a single heat. The requirement of fairly sizeable reservoirs to receive the large volume of the initial pour, and also sufficiently enlarged piping to permit gating of molds remote from the main sprue resulted in yields in the range of 20 to 30 per cent.

Work was done to refine these gating systems in an attempt to increase the yields and to decrease the amount of actual piping required to convey metal to the mold. Most promising were graphite pouring cups and main sprues connected at the bottom with short lengths of graphite tubing to a gating system in expendable mold material, which permitted distribution of metal to each of the vertical gates in a series of stacked molds, as shown in Figs. 8 and 8a.

Gating techniques are still not fully developed for centrifuge pouring, however, several procedures were used which are feasible for commercial production. The bottom gating methods were effective in centrifuge pours in the same way that they were effective for static pours. The essential requirements were that metal be introduced from the outer diameter of the spin circle and from the trailing edge of the casting, and in such a way that turbulence was minimized at the point of entry. Examples of this type of gating are shown in Figs. 9, 10 and 11. The gating ratio currently being used is a 1:2:2 gating system which provides a nonturbulent filling of the mold cavity. Gating ratios of 1:1.8:1.8 have also been used with success. A variation of this gating is shown in Fig. 12.

The gating ratios are established by reference to areas of sprue, runner and ingates. In the cited ratio 1:2:2 the one is the area of sprue, 2 is twice the area of the sprue and the area of the runner, the second 2 is twice the area of the sprue and the area of the ingates into the casting.

MACHINED GRAPHITE MOLDS

While machined graphite molds are most economically limited to simple shapes, which upon contraction after solidification do not destroy the details of

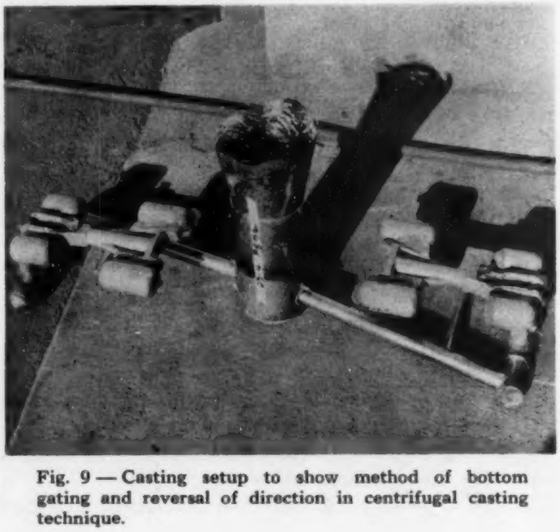


Fig. 9 — Casting setup to show method of bottom gating and reversal of direction in centrifugal casting technique.

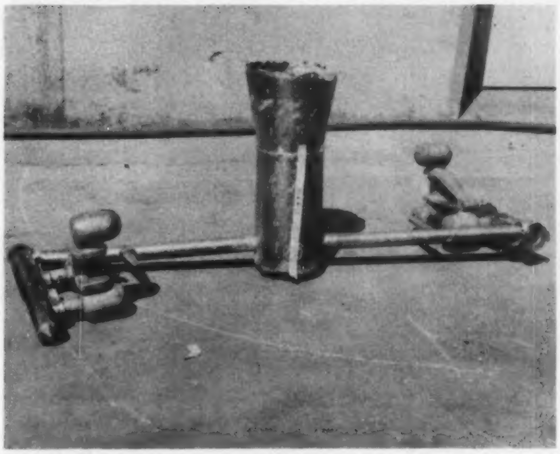


Fig. 10 — Casting setup to illustrate gating system in centrifugal casting reversed gate and reduced ingates to equalize metal flow through ingates.

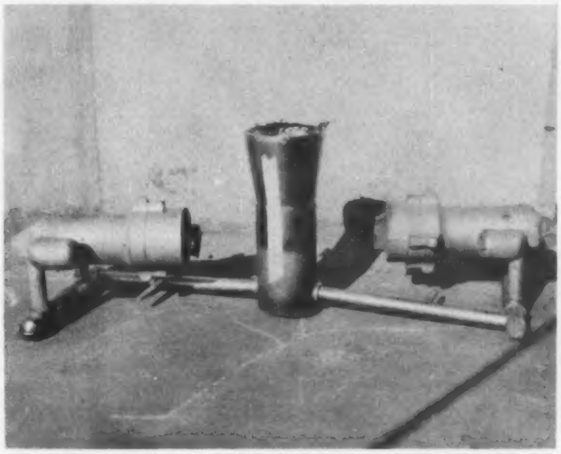


Fig. 11 — Casting setup to show centrifugal gating technique, shell graphite cores used in forming center of part.

the mold, many complex shapes can be produced this way. Figure 13 illustrates the complexity of a machined graphite mold necessary to prevent mold damage. Several examples of shapes produced in machined molds from CS grade graphite are shown in Figs. 14, 14a and 14b.

While surface appearance of these castings (Fig. 14) is good and dimensional accuracy is closely controlled, the reduced feeding distances, as discussed in an earlier section, require the application of excessive padding to promote directional solidification. Designs such as the flap track link (Fig. 14a) destroy the details of the mold during contraction and therefore, are not economical to produce.

The enclosed cored area of the bracket (Fig. 14) results in contraction cracks around the core when a machined graphite core is used. It has been found effective in some cases to use the machined mold for the exterior of the surface of the casting, and to use expendable shell or rammed graphite cores for the internal areas. Figure 15 illustrates the use of a shell graphite core in a machined graphite mold.

The rammed cores will crumble sufficiently to permit the necessary contraction of the casting. The machined mold also finds useful application for short run items where it is economical to produce the machined mold in lieu of having a pattern made. The machined mold was first used extensively for centrifuging castings, but many of these machined molds have been replaced with expendable molds in the centrifuging operation.

The increase in carbon content above base carbon on the surfaces of castings produced in the machined molds has been shown to be relatively shallow (Fig. 16).

Recent work has shown the machined mold to be unsatisfactory for aircraft quality on casting surfaces. Rapid chilling causing surface laps, and restricted contraction produces shallow tears or cracks (Fig. 17), which result in indications when dye penetrant inspected. The conclusion has been that where cast

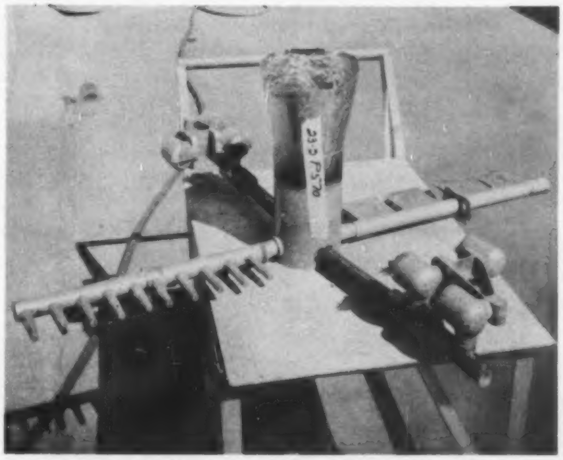


Fig. 12 — Casting setup to show variation in centrifugal gating system.

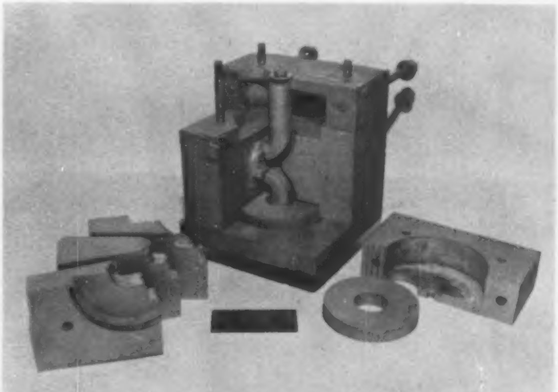


Fig. 13 — Complex machined graphite mold used to cast a valve body.

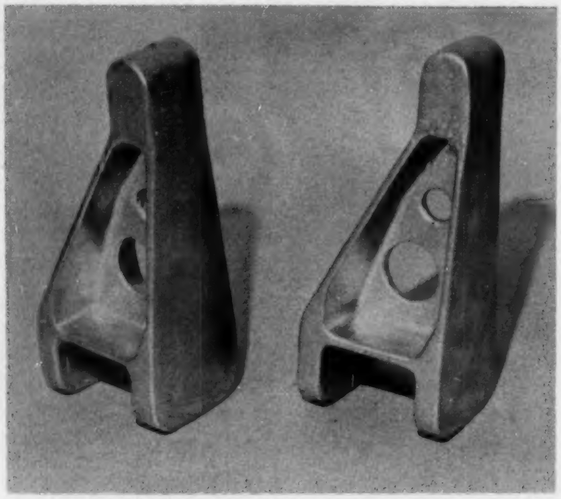


Fig. 14 — Bracket casting illustrating the surface finish obtained on castings made in machined graphite (right) and rammed graphite (left) molds. Both castings made with shell graphite cores.

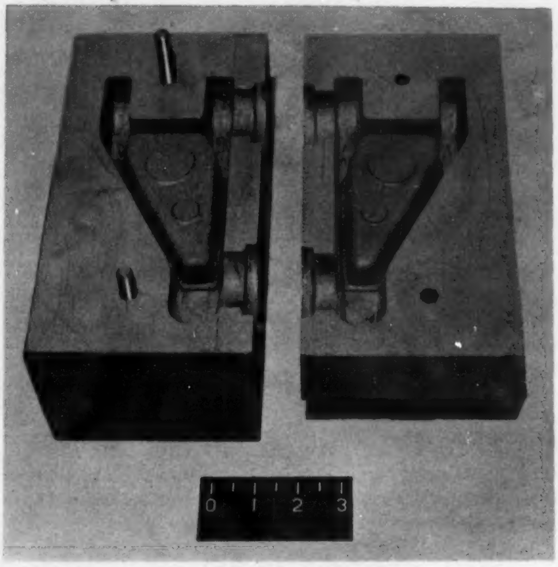


Fig. 15 — Use of shell graphite cores in machined graphite molds to prevent casting damage by cracking.

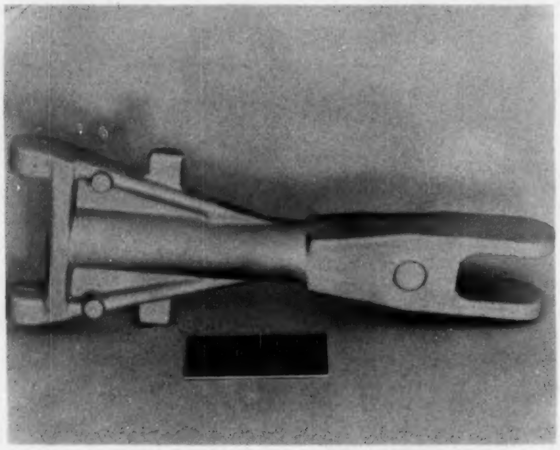


Fig. 14a — Link casting illustrating surface finish of part cast in machined graphite mold.

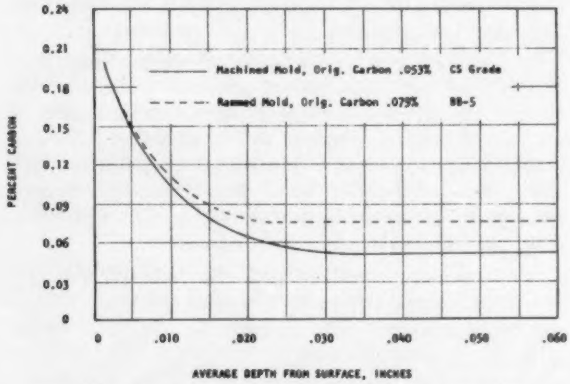


Fig. 16 — Carbon contamination in cold graphite molds. Casting section thickness — ½-in.

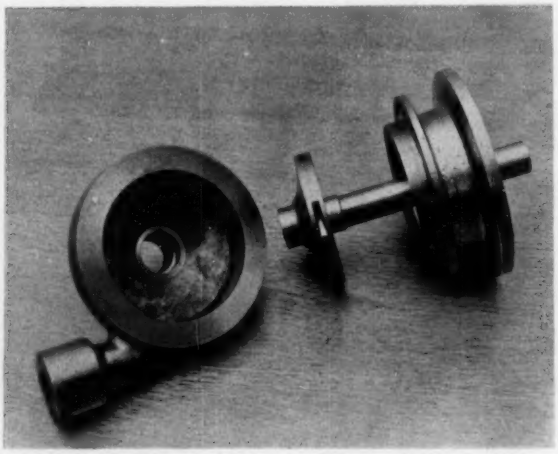


Fig. 14b — Pump housing, impeller and cover plate cast in machined graphite mold.

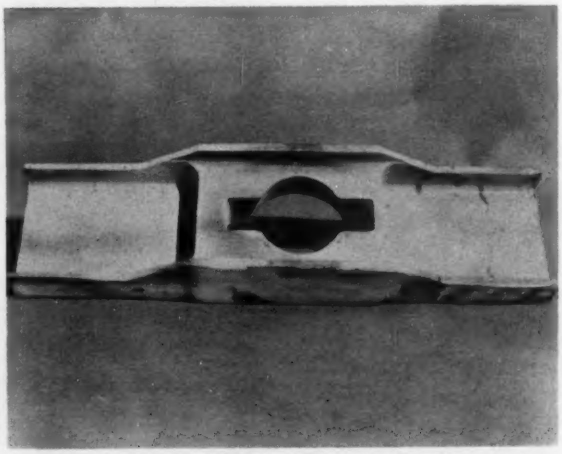


Fig. 17 — Surface cracking caused by rapid chilling and restrictions of machined graphite mold.

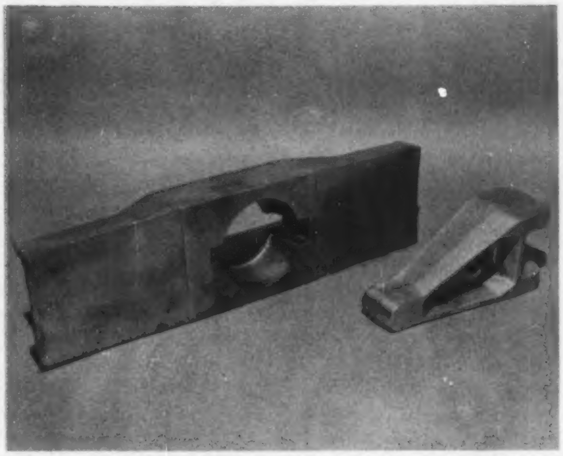


Fig. 18 — Shapes in rammed graphite molds by centrifugal techniques.

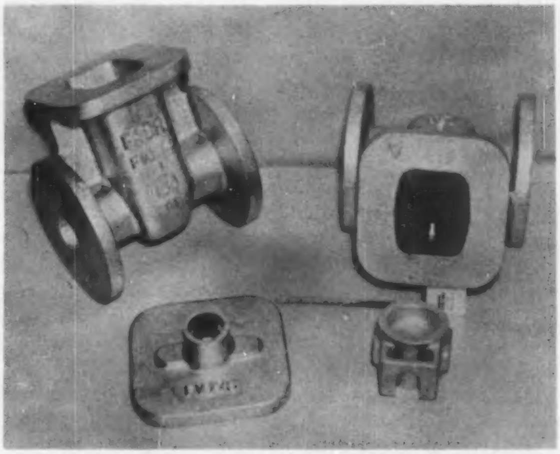


Fig. 18a — Valve components cast in rammed graphite molds by static casting techniques.

TABLE 1 — EXPENDABLE GRAPHITE MOLD MIX

Graphite Powder, %	70
Laundry Starch, %	5
Black Foundry Pitch, %	10
Carbonaceous Cement, %	8
Water, %	7
Total, %	100

TABLE 2 — PROPERTIES OF EXPENDABLE MOLD MIXES

Moisture Content	6.9
Green Permeability	190.0
Green Hardness	80.0
Green Compression	7.0
Fired Tensile Strength	70.0
Fired Scratch Hardness	65.0

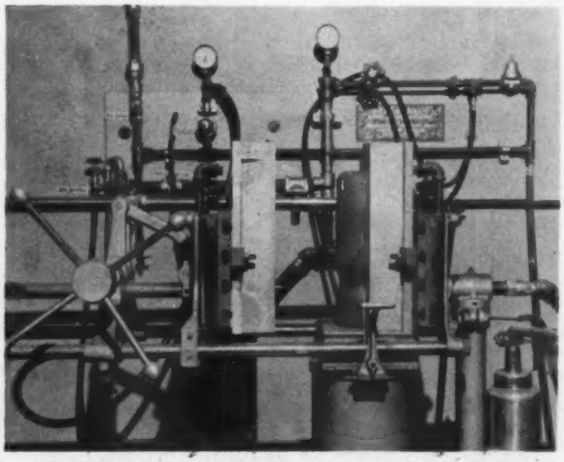


Fig. 19 — Shell core machined with core box and shell graphite core in place.

surfaces are required, machined graphite molds should not be used.

EXPENDABLE GRAPHITE MOLDS

The expendable graphite mold permits all the latitude of complex designs normally obtainable with any of the sand casting processes. Five successful mixes now being used are composed of essentially the same materials as reported for the mix shown in Table 1. Molds may be produced by hand ramming, pneumatic ramming and jolting and squeezing. Green and fired mold properties are shown in Table 2.

Feeding distances are extended over machined graphite molds as discussed and frequently, because of the more complex designs, permit feeding con-

Fig. 20 — Shell graphite cores for use in casting titanium alloys.

siderably beyond that shown from simple shapes. Surface finishes are frequently equal to finishes obtained in machined graphite, and generally comparable to many steel, iron, brass and aluminum sand castings. Examples, shown in Fig. 18 and 18a, of castings made in expendable graphite indicate that surface quality is approaching a high degree of acceptability.

The expendable molds do not produce hot tearing in titanium castings. The depth of carbon contamination in castings poured in cold expendable molds is not greatly different from that shown for castings produced in machined graphite, as seen as Fig. 16. As discussed earlier, the rammed mold is extremely hydroscopic, and extreme care is required in mold handling to insure control of the gassing problem.

The rammed mold presents a greater problem in dimensional control of a casting due to the mold shrinkage of approximately 1/8-in./ft during the baking and firing cycles. Fortunately, this shrinkage has been found to be relatively consistent, however, tolerances in the range of 0.010 to 0.015 in./in. are still required.

SHELL CORES OF GRAPHITE

An interesting development of new mold materials has been the production of a graphite shell core composed of a mixture of 80 per cent graphite powder, 12 per cent phenol formaldehyde resin and 8 per cent pitch.[6] The shell core is first produced in the usual manner, using the apparatus shown in Fig. 19, followed by the 1650 F firing cycle as given the expendable rammed mold and is then ready for use. Considerably improved production cycles have been obtained since there is no air dry and no baking time required before firing.

This frequently results in a saving up to 48 hr of process time. Excellent surface finish has been obtained, as shown in Fig. 15 (castings) and Fig. 20 (shell cores), and no contamination of the titanium castings has been experienced other than the usual increase of carbon on the casting surface. The cores are sufficiently strong to withstand centrifuging, as shown in Figs. 10, 11 and 12. The castings shown in Figs. 10 and 11 were made using shell cores. Excellent surface finish was obtained in each of the casting experiments.

Penetration of the shell cores is not influenced detrimentally by the increased forces prevalent during centrifuging. Warping of the shell cores has not been experienced during pouring of the castings. The increase of feeding distance in the casting due to the low heat capacity of the shell core promises to be an extremely valuable aid in solving some of the low feeding distance problems previously discussed.

The feeding distance in shell graphite molds is approximately twice that of rammed graphite molds. The shell core also permits easy removal of core from the casting when compared with either the machined or rammed cores. The principle problems remaining to be solved for producing a consistently satisfactory core are few. The high thermal conductivity of the graphite grain makes a long flow, slow cure resin most desirable for producing a dense core.

The shell cores shrink during final firing in the range of 0.014 to 0.017 in./in., and require careful packing to prevent warpage during the firing cycle.

CONCLUSION

Based on the preceding work, the following statements summarize the conditions of soundness found in titanium castings and the procedures which contribute to high levels of internal and external integrity.

Shrinkage occurs in well defined voids, which may be dispersed along section centerlines or concentrated at the center of heavy thermal sections.

Gas porosity is assumed to exist in connection with shrinkage, but will also be found in positions not related to thermal centers. Most effective in controlling the occurrence of gas porosity or shrinkage porosity is the application of centrifugal force during casting.

Feeding distance of titanium statically cast in graphite molds is less than twice the section thickness in uniform thickness sections when poured in cold molds, and within the range of superheat in the skull melting furnace.

Bottom gating techniques are essential for non-turbulent filling of the mold for both static and centrifuged castings. Gating ratios of 1:2:2 have been satisfactory.

Machined graphite molds are unsatisfactory for producing aircraft quality surfaces, because of surface cracking problems.

Expandable rammed graphite is the most satisfactory mold material available.

Shell cores of graphite, resin and pitch mixture can be processed to reduce reaction with titanium to below problem levels.

ACKNOWLEDGMENT

The authors wish to express appreciation to Boeing Airplane Co. and to the AMC Aeronautical Systems Center, LMBMB, for permission to publish this paper which is based, in part, on research conducted under Subcontract No. 2-669900-8125 and Contract No. AF 33 (600)-36450. Acknowledgment is given to Messrs R. V. Carter of Boeing Airplane Co., and R. G. Hardy of Oregon Metallurgical Corp., for their guidance and assistance with the Titanium Castings Development Program.

REFERENCES

1. R. V. Carter, "Development of Titanium Alloy Castings," Contract No. AF33 (600) -36450, Report No. 2, p. 5 (June 1958).
2. R. V. Carter, "Development of Titanium Alloy Castings," Contract No. AF33 (600) -36450, Report No. 2, p. 6 (June 1958).
3. R. V. Carter, R. J. Hogan, "Development of Titanium Alloy Castings," Contract No. AF33 (600) -36450, Report No. 6, pp. 17-18 (June 1959).
4. R. V. Carter, R. G. Hardy, "Development of Titanium Alloy Castings," Contract No. AF33 (600) -36450, Report No. 4, pp. 3-11 (Dec. 1958).
5. A. L. Feild, Jr., and R. E. Edelman, "The Use of Expendable Graphite Molds in the Production of Sound, Ductile Titanium Castings," AFS Transactions, *vol. 65*, pp. 517-522 (1957).
6. R. V. Carter and R. G. Hardy, "Development of Titanium Alloy Castings," Contract No. AF33 (600) -36450, Report No. 4, pp. 41-56 (Feb. 1959).
7. K. R. Grube and J. G. Kura, "Principles Applicable to Vertical Gating," AFS Transactions, *vol. 63*, pp. 35-48 (1955).

HIGH STRENGTH CAST STEEL STRUCTURE AND MICROPOROSITY EFFECT ON MECHANICAL PROPERTIES

by S. Z. Uram, M. C. Flemings and H. F. Taylor

ABSTRACT

The interrelationship of casting grain structure, microporosity and ductility is demonstrated for high strength, low alloy steel castings. These relationships are based on experimental work consisting of microradiography, examination of macrostructures and evaluation of mechanical properties of test castings. The test castings (solid cylinders, plates and step wedges) were produced under carefully controlled conditions to obtain desired variations in solidification structure.

Results show that microporosity has a drastic influence on the properties of high strength steel, and that it can be nearly eliminated by maintaining steep thermal gradients during solidification. When extremely sound metal is obtained, values of reduction in area of up to 40 per cent can be obtained at a strength level of 250-300,000 psi (in high purity A.I.S.I. 4340 steel). Columnar zones of the test castings produced were found to be most ductile and least prone to microporosity, since the conditions which favor columnar grain formation are also those that promote good feeding.

INTRODUCTION

There is a growing awareness on the part of design engineers of the benefits to be gained when sound, reliable, steel castings of ultra-high strengths become readily available. When cast steels with strengths of 300,000 psi (and with adequate ductility and impact strength for engineering applications) become obtainable, their advantages will include a higher strength-to-weight ratio than the best forged aluminum or magnesium alloys now obtainable or anticipated. Also, the time and cost of producing such castings will in many cases be far less than producing forgings or fabrications of comparable quality.

Work reported herein was conducted during the second year of what is planned as a continuing research program on the effect of solidification variables on mechanical properties of high strength cast steel. The program is fundamental in nature, but has the ultimate objective of developing the basic information necessary to produce steel castings reliably and economically with good ductility at the 300,000 psi strength level. Support is from Army Ordinance through Rodman Laboratory, Watertown Arsenal. Previous publications describe earlier work,[1,2] and a recent report to Watertown Arsenal describes the work reported herein in more detail.[3]

During the first year of this program, a preliminary investigation was conducted of the effect of solidification variables on 1) microsegregation, 2) microshrinkage and 3) inclusion count and distribution. An important conclusion was that microporosity (in castings which are apparently sound when examined by ordinary techniques) is an important factor limiting ductility of high strength cast steels. Ductility is a factor of prime importance in these steels because ductility and strength are inversely related. If exceptionally high ductility can be obtained in a given steel at a given strength level, then the strength of that steel can be readily increased (by changing the heat treatment or increasing carbon content) while still retaining adequate ductility for engineering application.

Work during the second year, described in this paper, has dealt extensively with theoretical and experimental studies of 1) effect of solidification variables on casting macrostructure, i.e., columnar or equiaxed grains, 2) effect of solidification variables on microporosity, 3) techniques for careful measurement of microporosity in steel castings and 4) effect of structure and microporosity on mechanical properties, particularly ductility. A low alloy high strength steel (A.I.S.I. 4340) was used throughout the study.

CASTING STRUCTURE, MICROPOROSITY AND MECHANICAL PROPERTIES

Casting Structure and Its Effect on Mechanical Properties

While the mechanical properties of castings are usually (and reliably) isotropic, specialized solidification conditions can produce castings with properties that are quite different in different directions. Walther, Adams and Taylor[4] investigated casting "fiber" in aluminum alloys by performing mechanical tests on

---

S. Z. URAM is Rsch. Assoc., M. C. FLEMINGS is Asst. Prof., and H. F. TAYLOR is Prof., Dept. of Met., Massachusetts Institute of Technology, Cambridge.

(A major portion of this paper is based on a thesis by Stuart Uram at the Massachusetts Institute of Technology in partial fulfillment of the degree of Doctor of Science.)

materials which were solidified with a wholly columnar macrostructure. Their work showed that tensile strength and ductility were markedly greater for test bars taken parallel to the columnar grains than for bars tested across these grains. It was concluded that the low transverse properties were due to microporosity and brittle segregate that lined up between the grains during solidification.

Northcott[5] also found anisotropy in copper castings which were solidified with elongated columnar grains. In this case, the mechanical properties were lowest when pulled along the direction of the axis of the columnar grains (in contrast to the case of aluminum). The best properties were obtained when the structure of the cast material was equiaxed. Tensile specimens oriented transversely to the axis of the columnar zone showed intermediate strengths.

It appears that porosity or segregate had little effect on mechanical properties in Northcott's material, and the variation in properties with varying structures was due solely to crystallographic (or grain boundary strengthening) effects.

Variation of mechanical properties of cast steel with type of structure has been investigated by Northcott[6] and by Reynolds and Preece.[7] Northcott found, in the course of an investigation to determine the effect of turbulence on solidification structures of plain carbon steel, that the mechanical properties of cast steel in the equiaxed zone were inferior to properties in the columnar zone. He attributed these lower mechanical properties to the increased amount of porosity at the center of the casting, although no evaluation of the amount of porosity was undertaken at the time.

Reynolds and Preece found slight differences (about 2000 psi) in strengths between crystals in the equiaxed zone and those in the columnar zone; however, the ductilities were markedly different. Percentage reduction in area for metal from the columnar zone was 47 per cent, compared to 28 per cent reduction in area for metal from the equiaxed zone.

Equiaxed Zone Porosity

Reynolds and Preece[7] also related structure to degree of microporosity, and found the equiaxed zone more prone to occurrence of microporosity than the columnar zone. It appears that the high reductions in area they obtained in the columnar zone were due to the low amounts of microporosity in this region. This explanation agrees with the findings of Jackson,[8] who showed that the degree of ductility increases as the amount of microporosity decreases.

It should be emphasized that the work cited above has been conducted on commercial grade steel (70,000 psi); "microporosity" considered was of a more gross type than that dealt with in the present investigation. More recent work has indicated that microporosity, even in much smaller amounts, is an important factor limiting mechanical properties of high strength steels.[2,9]

The changes produced in the length of the columnar zone and the size of the grains in the equiaxed zone have been investigated from various standpoints, including the action of grain refining materials, convection, turbulence and pouring temperature. Cibula[10] investigated the effect of grain refining additions to aluminum alloys, and showed that the length of the columnar zone and grain size of the equiaxed zone are both greatly reduced by the addition of grain refining materials. Gray[11] found that by inserting a chill rod in the riser of a top fed casting, the columnar zone was reduced.

This result was attributed to introduction of convection currents due to the chill rod. However, in the case of aluminum alloys, Hucke, Adams and Taylor[12] have shown that under steep thermal gradients increasing the degree of stirring increases the tendency to form columnar grains. Reynolds and Preece[7] established through the use of stearin wax that a high degree of convection can exist prior to solidification. Northcott[13] investigated the role of alloying elements and their effect on the length of the columnar zone. He was able to distinguish experimentally between elements which increase, decrease or do not affect the length of the zone in copper base materials.

Factors Affecting Formation of Columnar Zone in Steel Castings

The structure of the columnar zone and the details of its formation are of practical, as well as research, interest since 1) this structure is commonly found in steel castings and 2) the mechanical properties of metal from the columnar zone are usually higher than the properties of metal from the equiaxed zone. Requirements for the formation of this zone have been discussed by Chalmers,[14] Tiller and Rutter,[15] Walker[16] and Hucke, Flemings, et al.[17] During solidification of an alloy, solute is rejected to the liquid by the growing solid.

This rejection results in formation of a boundary layer in the liquid (immediately ahead of the growing solid) which is richer in solute than the bulk liquid composition. Formation of the boundary layer, its thickness and factors which affect it have been discussed by Wagner.[18] An important result of solute rejection during solidification is that it depresses the freezing temperature (liquidus temperature) of metal in the boundary layer adjacent the growing solid. Figure 1a shows this depression schematically as a function of position in the liquid metal.

It is possible to add to Fig. 1a the actual temperature distribution existing in a solidifying casting. Figure 1b shows one possible case. In this example (Case I), temperature gradients are steep enough so that there is no point in advance of the interface that lies below the liquidus temperature at that point. In this case, solidification is "plane front;" dendrites do not form and the resulting casting is composed of large grains completely free of any microsegregation. This type of solidification can occur only with extremely pure metals or when special techniques are employed.[17]

If the actual temperature gradient in the casting is slightly less steep than that shown in Fig. 1a, the situation shown in Fig. 1c (Case II) results. Here, at a point in advance of the interface, metal is below the temperature at which freezing can occur; the plane front of Case II is now unstable and a tendency exists for columnar grains (columnar dendrites) to reach out into this "constitutionally supercooled liquid."[15] A discussion is given later in this paper of

thermal and metallurgical factors which 1) promote columnar grain formation and 2) lead to breakdown of columnar grains with consequent equiaxed grain solidification in Fig. 1d (Case III).

Factors Affecting Formation of Equiaxed Zone During Solidification

The formation of the equiaxed zone has historically been the least well understood of the grain structures found in castings and ingots. In one of the first systematic investigations of casting structures, Scheil[19] was unable to explain the formation of the central zone of equiaxed grains. He referred to it as abnormal nucleation, since it did not agree with the laws of crystallization set forth by Tammann.[20] He recognized that nuclei must be present in the central portion of the casting, since grain refinement in this region was found to result from inoculation treatments, reduction in pouring temperature and reduction of mold temperature.

He also found a marked reduction in the length of the columnar zone as pouring temperature and mold preheat temperature were decreased. He offered two possible explanations for these observations 1) that the nuclei were the result of movement of particles away from the growing solid and 2) that the grain refinement was related to what we now call "constitutional super-cooling," the building up of low melting point liquid around a solid which inhibits further growth of the solid.

Scheil's first concept had (and still has) merit for understanding certain nucleation phenomena. His idea was supported by his experiments with vibration which were found to refine the grain size. Genders[21] suggested this refinement results from the fracture of dendrites, although other explanations (Friedman and Wallace[22,23]) are possible. Also, Papapetrou[24] suggests secondary branches of dendrites may be removed from the main spine by solution at the base of the secondary branches.

Consideration of Scheil's second concept above leads immediately to reconsideration of the boundary layer theory outlined earlier, and sketched graphically in Fig. 1. Briefly, when the temperature gradients in a solidifying casting are relatively shallow (Fig. 1d, Case III) the degree of supercooling may be sufficient that nucleation occurs ahead of the interface and an equiaxed grain structure results. The amount of supercooling necessary to achieve this nucleation depends on the state of the metal bath, i.e., presence or absence of impurities, grain refiners or the application of such external factors as vibrations.

Summary of Metallurgical and Thermal Factors Affecting Solidification Structure of Cast Metals

Based on the preceding discussion and on pertinent references,[14-18] it is possible to delineate the factors which, if wholly controlled in steel castings, could result in completely controlled grain structures. With reference to Fig. 1, the following procedures will increase the columnar zone in steel castings:

1) Increase the steepness of the temperature profile. i.e., introduce steep temperature gradients by chilling and/or application of insulation or heat.

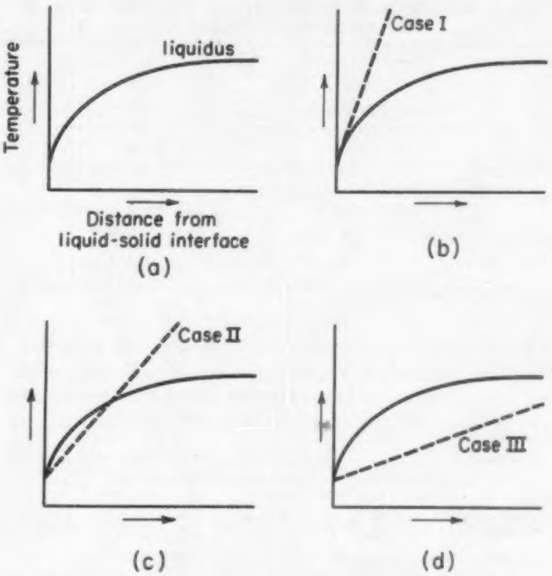


Fig. 1 — Conditions for the formation of cast structures — a) depression of the liquidus temperature adjacent to the solid-liquid interface as a result of solute rejection during solidification, b) steep temperature gradients (dotted line) result in absence of constitutional supercooling and plane front solidification, c) less steep temperature gradients produce small amount of constitutional supercooling and result in formation of columnar dendrites and d) shallow temperature gradients produce larger amount of constitutional supercooling and equiaxed grains form.

2) Decrease steepness of the liquidus profile. This can be done experimentally by such techniques as stirring, slow solidification or alteration of analysis.[17]
3) Decrease amount or availability of potential nuclei.

Essentially, the above delineation comprises the foundation for the experimental work described herein. Work consisted of alteration of cast structures by the procedures listed above (primarily by control of the temperature profile during solidification and by control of available nuclei); physical and mechanical properties of the castings produced were then examined.

PROCEDURE

General

Three types of castings (plates, solid cylinders and step wedges) were gated, risered and chilled in several ways to produce variations in macrostructures, feeding conditions and freezing rates. Each casting was subjected to the following program:

1) The macrostructure was examined by sectioning and etching with a neutral solution of copper ammonium chloride.
2) The mechanical properties of heat treated samples from various locations were measured by tensile and impact testing.
3) A microradiographic survey was made of the amount of microporosity existing at various locations.

TABLE 1 — EXPERIMENTAL MATERIALS AND PROCEDURE

Alloy —	Element	%
	C	0.40
	Mn	0.80
	Si	0.30
	Cr	0.80
	Ni	1.80
	Mo	0.25
	P	less than 0.1
	S	less than 0.1

Mold Material —	No. 80 Silica Sand, lb. . . 100
	Cereal, lb. . . . 0.5
	Dextrin, lb. . . . 0.5
	West. Bentonite, lb. . . . 4.0
	Water, lb. . . . 3.2
Exothermic Material —	Proprietary nonmetal producing exothermic material, mulled, rammed and baked at 600 F overnight.
Macrostructure Etchant —	120 grams Cupric Ammonium chloride dissolved in 1000 cc water.

Heat Treatment —	Temp., F	Time, hr.	Quench
	2200	3	Air cool
	1750	3	Air cool*
	1600	3	Furnace cool to 1400 F
	1400	2	Oil quench
	400	2	Water quench
	400	2	Water quench

*Samples were shot blasted after this treatment to remove scale.

All experimental heats were of low alloy, high strength steel (A.I.S.I. 4340). Castings were produced in green sand molds. Chills and/or exothermic inserts were used where required. Pertinent information regarding nominal analysis, mold material, etchant and heat treatment is given in Table 1. Table 2 presents chemical analysis data for all heats.

TABLE 2 — CHEMICAL ANALYSIS OF EXPERIMENTAL HEATS

		Element, Wt. %							
Heat	Casting	C	Si	Mn	Cr	Ni	Mo	P	S
A	Cylinders	0.41	0.30	0.69	0.79	1.91	0.24	0.008	0.012
B	Cylinders	0.37	0.31	0.87	0.80	1.88	0.25	0.010	0.008
C	Cylinders	0.40	0.40	0.82	0.85	1.77	0.25	0.007	0.015
D	Plate	0.38	0.32	0.72	0.87	1.87	0.25	0.007	0.009
E	Step Wedge	0.40	0.31	0.99	0.97	2.27	0.27	0.009	0.011
F	Step Wedge	0.40	0.28	1.01	0.80	2.03	0.24	0.005	0.012
	Aim Analysis	0.40	0.30	0.80	0.80	1.80	0.25	——	——

Melting Practice

Melting was carried out in a magnesia-lined induction furnace of 300 lb capacity. Electrolytic iron, ferromolybdenum and electrolytic nickel squares were initial charge materials. At meltdown, ferrosilicon containing approximately 50 per cent silicon was added to the melt. Carbon was then introduced in the form of a master alloy of high purity iron containing 4.2 per cent carbon. Chromium was added as ferrochrome.

The melt was heated to 3020 F, ferromanganese added, and poured at 3100 F into a preheated magnesia-lined ladle containing a proprietary calcium-manganese silicon deoxidizer (0.4 weight per cent); 0.1 weight per cent aluminum was added to the ladle when two-thirds of the heat had been tapped. Temperatures during melting were measured with an optical pyrometer; ladle temperatures were measured with an immersion thermocouple (platinum-platinum 13 per cent rhodium).

Microradiography

The technique of microradiography consists in placing a thin sample in the beam of x-rays and collecting the transmitted image on photographic film. Generally, the photographic film is placed in direct contact with the sample so a one-to-one correspondence is obtained. However, the sample may be removed some distance from the photographic emulsion, and the image enlarged directly. Trillat[25] has reviewed the fundamental aspects of this technique and its value for many types of investigations. The more important factors, as related to the study of microporosity in castings, are given here.

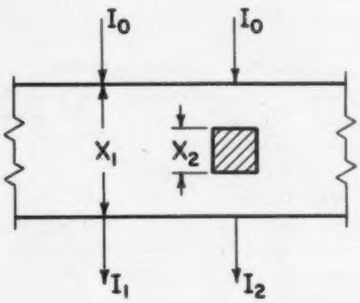


Fig. 2—Geometric conditions for microradiography. X_1 is plate thickness and X_2 is thickness of void (or second phase).

Figure 2 points out the essential geometric conditions whereby microradiography is able to distinguish a second phase (or microcavity) in a material. Consider a beam of x-rays of intensity I_0 falling on a sample of thickness X_1 containing a second phase of thickness X_2. The absorption coefficient of the homogeneous material is μ_1 and the absorption coefficient of the second phase is μ_2. The ratio of the intensity of the transmitted ray through the homogeneous material (I_1) to the intensity of the ray transmitted through the second phase (I_2) is the photographic contrast and is given by:

$$I_2/I_1 = \exp\{(\mu_1 - \mu_2)\, X_2\} \qquad (1)$$

If the second phase is a microcavity, then μ_2 is equal to zero so that equation (1) reduces to:

$$I_2/I_1 = \exp(\mu_1 X_2) \qquad (2)$$

Therefore, the choice of radiation on the basis of absorption coefficient is not of major importance in determining amounts of microcavities. However, it is desirable from a practical standpoint to allow μ_1 to be as small as possible in order to reduce exposure time and the possibility of scatter.

In the identification of a second phase, radiation wave length is important to obtain qualitative and

quantitative measurements. A plot of the linear absorption coefficient of a particular element shows a discontinuity at the absorption edge of the material. If a sample is x-rayed twice, once with radiation corresponding to a wave length where the absorption coefficient is high, and again with radiation where the absorption coefficient is low, then the sign of the difference between μ_1 and μ_2 is changed.

That is, in the first case the second phase appears light and in the second case the second phase appears dark. With the aid of published values of absorption coefficients, positive identification can be made. Such information for inclusions found in steels has been published by Homes and Gouzou.[26]

Photographic Film for High Magnifications

The choice of photographic film becomes important when high magnifications are considered. Since the negatives may be enlarged up to 500 times, the grain of the film can obscure the desired results. Engstrom and Lindstrom[27] have discussed the suitability of various types of emulsions for microradiographic use. Excellent emulsions include films and spectroscopic plates which have a resolving power of about 1,000 lines/mm. Unfortunately, films or plates which possess such high resolving power are extremely fine grained and, as a result, film speed is low. This factor results in extremely long exposure times. When magnifications of the order of 50 times are required, contrast process films are desirable since they require relatively short exposure times.

Perhaps the chief drawback to the microradiographic technique is the difficulty of preparing suitable test pieces. It is necessary that the specimen be thin (the order of 0.005 in. thick for the precision aimed for in this study), have good metallurgical polish on both sides and parallel faces. Several methods have been suggested for preparation of these samples.[28,29] Michael and Bever[28] prepared thin samples for autoradiography by mounting them in Lucite and machining them on a lathe. This method has the advantage of speed; however, the final machining operation is difficult since the specimens are fragile.

In this work, the requirements that the samples must be thin, smooth and flat were met by the following procedure. Specimens were mounted to a steel block with an epoxy resin mixture (Table 3).

TABLE 3 — EPOXY RESIN MIXTURE

Shell Epoxy Resin, ml	10
Hexahydrophthalic Anhydride, ml	11.5
Pyridine, ml	0.04

The samples were ground to a thickness of about 0.010 in., removed and remounted on a special sample holder similar to that suggested by Sharpe.[29] This holder consists of a large screw, 1¼-in. in diameter, in the center of a 2 in. square block.

After polishing the surface of the sample to an excellent metallographic finish, the sample is removed and the process repeated on the opposite surface. By placing the samples in the output of an x-ray tube such as the type employed for Laue photographs, an image of the microporosity can be obtained. Table 4 gives the pertinent x-ray data.

TABLE 4 — X-RAY DATA

Sample Thickness, in.	0.005
Film to Source Distance, in.	18
Film	Contrast process ortho
X-ray Tube	Copper target
Voltage, kv	40
Current, milliamps	7
Time, min.	5

The amount of microporosity was evaluated by placing a grid on the radiograph and counting the number of squares in which micropores were found. The amount of microporosity was then determined as:

$$\text{amount} = \frac{\text{no. squares containing micropores} \times 100}{\text{total no. squares}}$$

This method of rating microporosity results in a "per cent microporosity" that is considerably magnified with respect to true volume per cent. The magnification comes from the fact that the method, in effect, measures the relative area of microporosity, but does so on a specimen of finite thickness. The actual magnification probably depends somewhat on pore size as well as on experimental technique.

EXPERIMENTAL RESULTS

Cylinder Castings

A study was made of the effect of solidification variables on the structures of solid cylinder castings (4 in. diameter by 4 in. high, top risered). Three castings were poured from each heat, all from a common gating system (Fig. 3). Various techniques were employed to modify the structure of these cylinders, including 1) chill in the riser, 2) bottom chill, 3) vibrated chill in the riser, 4) vibrated steel box in the ingate and 5) unvibrated steel box in the ingate. Table 5 lists the heats poured and techniques employed to modify cast structures. In each heat a "standard" casting was poured with no treatment, for reference purposes. Macrostructures of the test castings were examined by etching vertical sections. Mechanical properties were determined by cutting test bars from locations shown in Fig. 4. Microporosity ratings were determined by point counting microradiographs.

All cylinder castings produced without special treatment (except for use of rice hulls on the risers) showed a relatively coarse, equiaxed grain structure throughout. Bottom chilling resulted in a columnar zone approximately 1½-in. long. Chilling also refined the size of the equiaxed grains slightly. A marked refinement of these equiaxed grains resulted when a chill rod was placed in the riser; this result was repeated in Heats[5] *A* and *B*.

Figure 5 shows the macrostructures of the three castings of Heat *B*, and illustrates 1) the chill rod in the riser effects significant grain refinement and 2) vibrating this rod has no additional grain refining effect (over the unvibrated rod). Consideration of the causes of this refinement has led to the conclusion that it is the result of nuclei formation in the region of the

TABLE 5 — CYLINDER CASTING TREATMENT

Heat No.	Casting No.	Design Variable
A	1	¾-in. steel rod, 2 in. long placed in the top of the riser.
	2	3 in. diameter cylindrical steel chill placed on bottom surface of the casting.
	3	standard gating system.
B	1	¾-in. steel rod, 2 in. long with an air vibrator placed in the top of the riser.
	2	¾-in. steel rod, 2 in. long placed in the riser.
	3	standard gating system.
C	1	2 x 2 x 4 in. steel box placed in the ingate with an air vibrator attached to the box.
	2	2 x 2 x 4 in. steel box placed in the ingate.
	3	standard gating system.

All heats were poured at a temperature of 2850 F.

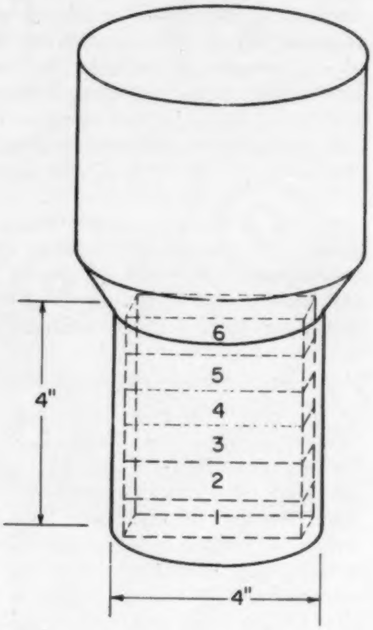


Fig. 4 — Cylinder casting design showing test bar locations.

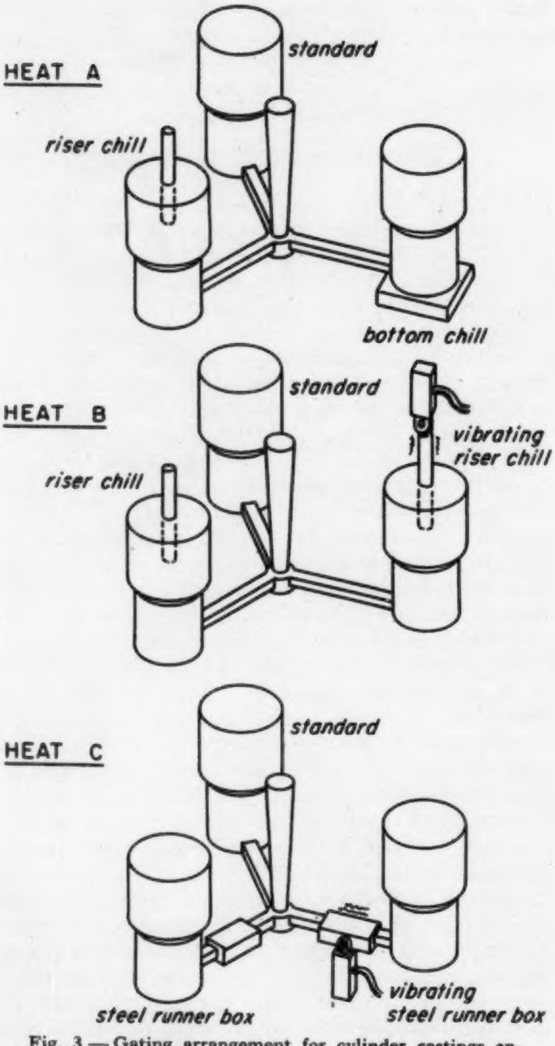


Fig. 3 — Gating arrangement for cylinder castings experiment.

chill rod, and the subsequent settling of these nuclei under the influence of gravity. This has been discussed in detail in the report on which this paper is based.[3]

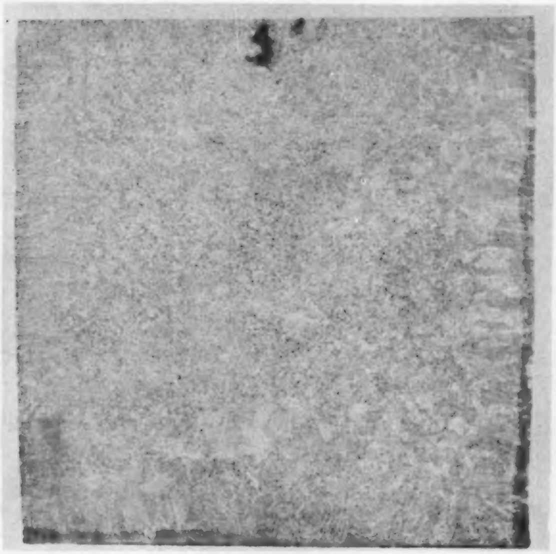
Agitation of the liquid steel immediately prior to entering the mold cavity resulted, surprisingly, in grain coarsening. This "denucleating" effect is seen by comparing the structure of the casting C-1 to the structures of other castings from the same heat (Fig. 6). The columnar zone of casting C-1 is extremely coarse, and grains in the central portion are the largest grains found in any of the experimental castings. Large grains of this sort are characteristic of high pouring temperatures and/or slow cooling rates. Since the grain size of the two other castings poured in the same mold do not exhibit such coarsening, it must be concluded that the grain coarsening was the result of vibration.

Mechanical Testing

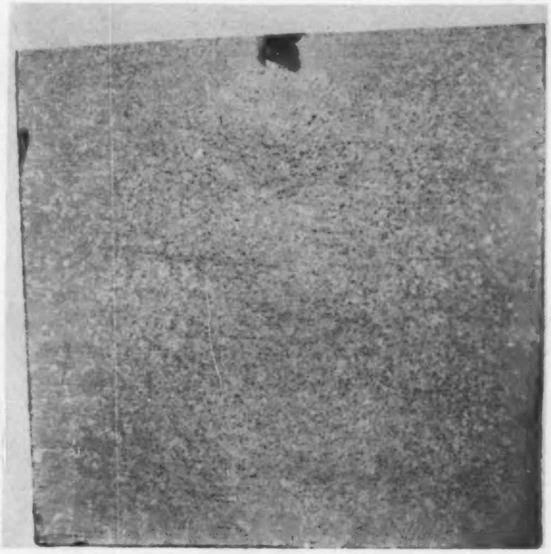
Results of mechanical testing (Table 6) show that yield and tensile strengths are not affected by small amounts of microporosity. Slight changes in strengths from heat to heat probably result from small variations in carbon content. However, there is a marked effect of microporosity on ductility. Low amounts of microporosity result in high values of ductility. For example, in one test bar cut from extremely sound metal (0.38 per cent porosity), reduction in area was 27 per cent. In a less dense region of the same casting (1.34 per cent porosity), reduction in area fell to 5.5 per cent.

These values were taken from the test casting A-2, a bottom-chilled casting. The chill, by increasing thermal gradients, enhanced feeding at the bottom of the casting. Table 7 summarizes data showing the relation between microporosity and reduction in area for the cylinder castings.

Grain refinement (and grain coarsening) achieved in this phase of the study had no apparent effect on



Casting B-1 —
Vibrated chill rod
in the riser.



Casting B-2 —
Chill rod in
the riser.

Fig. 5 — Macroetched vertical sections from cylinder castings. Castings B-1 and B-2 show grain refinement.

Casting B-3 —
Standard
comparison.

mechanical properties, including elongation and reduction in area. Refinement resulting from the chill rod in the riser did appear to reduce porosity somewhat (0.90 per cent compared to 1.00-1.30 per cent in the comparison casting). However, this reduction was not sufficient to affect ductility significantly.

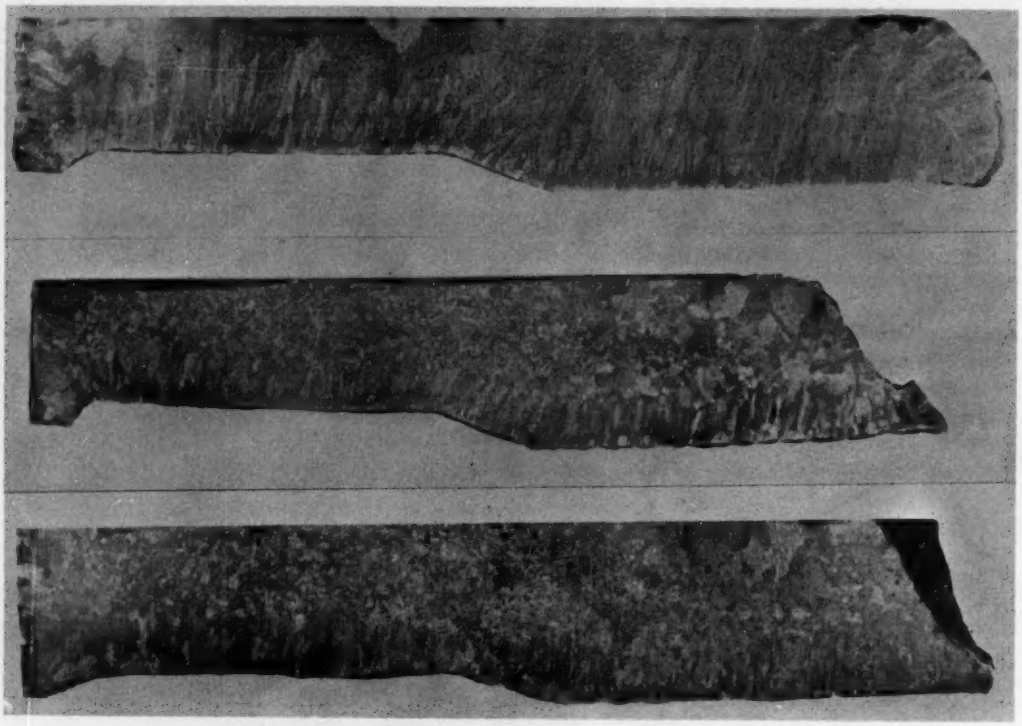
Impact data (Charpy impact, —40 F) were obtained from a number of the cylinder castings described herein. Results ranged from 5 to 12 ft-lb and averaged 9 ft-lb. No correlation could be found between impact properties and microporosity.

Plate Casting Experiments

A series of plate castings of various lengths were poured. The plates were ½-in. thick and 5 in. wide and were end-risered (Fig. 7). Plates were cast of 5, 3 and one in. lengths. One series of plates were chilled at the end opposite the riser, whereas a second comparison series were cast unchilled.

As a result of careful examination of the amount of microporosity present along the lengths of the plates (by the microradiographic technique described), and correlation of this porosity with location in the plate and with mechanical properties, Figs. 8 and 9 were prepared. More complete results are presented in Table 8. Major conclusions to be gained from these data are 1) a definite correlation exists between microporosity and ductility in the plate castings and 2) tensile and yield strengths are relatively unaffected by microporosity (in amounts studied).

In all plates, chilled and unchilled, only small amounts of microporosity were present in the vicinity of the plate end. However, this porosity increased with increasing distance along the plate. Figure 8 pre-



Casting C-1 — Vibrated chill box in the gate.

Casting C-2 — Chill box in the gate.

Casting C-3 — Standard comparison.

Fig. 6 — Macroetched vertical sections from cylinder castings (only one side of each casting is shown). Casting C-1 shows grain coarsening.

TABLE 6 — MECHANICAL PROPERTIES OF CYLINDER CASTINGS

No.*	Treatment	Structure	Loc.**	Y.S. 0.2% offset lb/in.^{2}	T.S., lb/in.^{2}	Elong., %	Red. in area, %
A-1	chill rod	fine grain	1	228,500	277,500	7.9	16.1
	in the riser	size in the	3	225,000	271,500	7.1	13.0
		center zone	5	224,000	267,500	4.3	5.5
A-2	chill on	columnar zone	1	218,000	270,000	10.7	27.0
	the bottom	on the bottom	3	219,500	271,000	6.4	13.0
		region	5	224,000	272,000	3.6	5.5
		coarse grains	T	232,700	281,000	4.0	5.5
A-3	comparison	in the center	3	218,000	272,500	5.0	7.1
	standard	zone	5	223,500	273,000	4.3	6.0
B-1	vibrated chill	fine grain	2	203,000	253,000	2.9	4.9
	rod in riser	size in the	4	204,000	255,000	3.6	6.0
		center zone	6	205,000	225,000	1.4	2.2
B-2	chill rod	fine grain	2	219,000	260,000	4.3	8.2
	in the riser	size in the	4	215,400	259,900	4.0	5.5
		center zone	5	215,000	253,600	5.0	8.8
B-3	comparison	same as	1	211,000	258,000	4.3	10.9
	standard	A-3	2	215,000	258,000	4.3	9.3
			3	215,000	254,000	2.1	4.4
			4	217,000	258,800	3.0	4.2
			5	219,500	264,600	5.0	5.6
			6	216,000	252,000	2.0	2.6
C-1	vibrated chill	coarse	1	211,000	265,000	3.6	3.8
	box in the	grains	3	208,000	250,000	1.4	1.6
	gate		5	209,000	263,000	4.3	7.1
			T	215,000	274,000	2.9	5.5
C-2	chill box	same as	2	211,000	266,000	4.3	7.6
	in the gate	A-3	4	217,000	264,000	3.6	6.6
			6	204,000	252,000	2.9	4.4
			T	206,250	260,000	3.6	9.3
C-3	comparison	same as	2	207,000	264,000	5.0	6.6
	standard	A-3	4	206,000	263,000	2.9	3.3
			T	211,000	268,000	2.9	4.9

*Letter refers to the heat, number to casting. All castings in a single heat were cast in the same mold.

**Number refers to Fig. 4. The letter "T" indicates a bar cut from the casting transverse to the other bars from a region at the outside of the cylinder.

TABLE 7 — MICROPOROSITY SURVEY ON CYLINDER CASTINGS

Casting	Location*	Porosity, %	Red. in Area,** %
A-1	1	0.84	16.1
A-1	2	0.90	13.0
A-2	1	0.38	27.0
A-2	3	0.53	13.0
A-2	6	0.13	5.5
A-3	1	1.17	
A-3	2	1.34	7.1
A-3	6	1.00	6.0
B-1	2	0.90	4.9
B-1	4	0.91	6.0
B-1	6	1.28	2.2
C-1	2	0.51	3.8
C-1	6	2.12	7.1
C-2	1	0.70	7.6
C-2	3	0.67	6.6
C-2	5	0.81	4.4

*Refer to Fig. 4.
**Value taken from test bar nearest indicated location.

sents data for two typical plates (3 in. long). In an end-chilled plate microporosity was essentially zero near the plate end and increased to one per cent 2 in. from the end. In an unchilled plate microporosity was essentially zero near the plate end but increased to 3 per cent 2 in. from the end.

Elongation and reduction in area generally decreased with increasing microporosity, while tensile and yield strengths were relatively unaffected. Values of reduction of area as high as 40 per cent were obtained near the end chill.

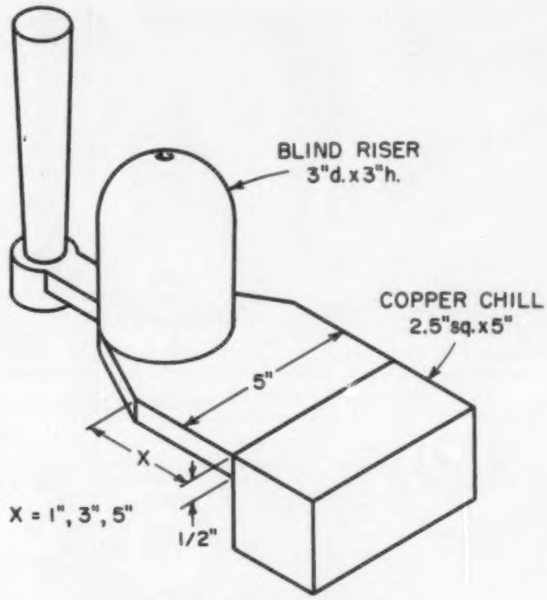


Fig. 7 — Design of plate casting.

Nondestructive Radiography

All plates cast in this study were apparently sound when examined by conventional nondestructive radiography. This was expected (except possibly for the 5 in. long, unchilled plates) from data on feeding distances in steel castings.[30] None-the-less, the presence of microporosity was evident in all plates when ex-

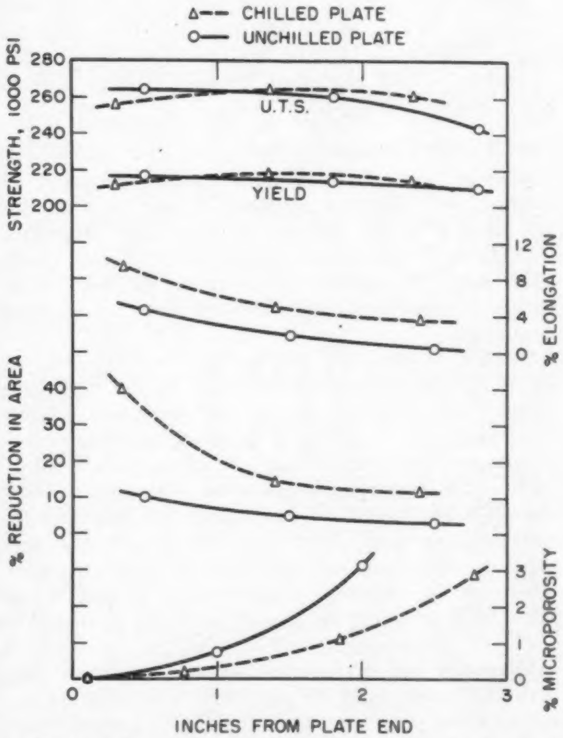


Fig. 8 — Summary of mechanical properties for 3 in. plate castings, heat *D*.

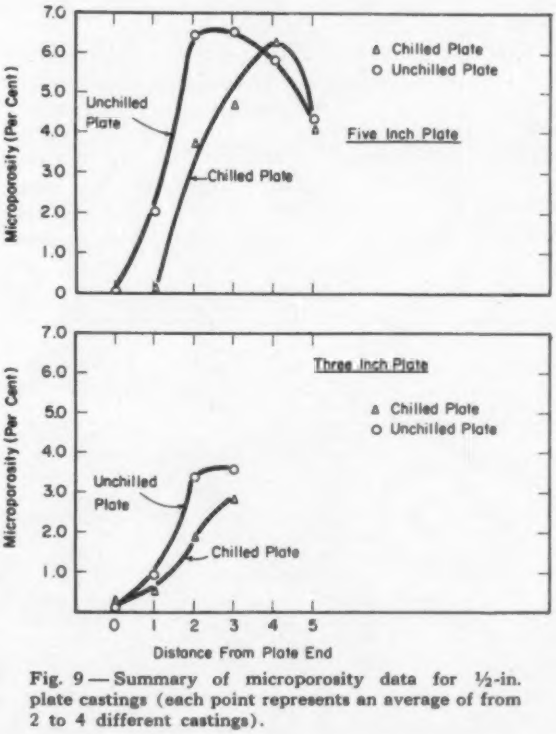


Fig. 9 — Summary of microporosity data for ½-in. plate castings (each point represents an average of from 2 to 4 different castings).

TABLE 8 — PROPERTIES OF PLATE CASTINGS

Description	Plate length, in.	Location[1]	Y.S. 0.2% offset lb/in.^{2}	U.T.S. lb/in.^{2}	Elong., %	Red. in Area, %	Micro-porosity, %
unchilled	1	0.5	216,000	262,000	5.7	15.6	0.90
chilled	1	0.5	216,000	264,000	7.9	27.0	0.10
unchilled	3	0.5	218,000	266,500	5.0	10.9	0.00
unchilled	3	1.5	216,000	262,000	2.1	5.5	0.71
unchilled	3	2.5	211,000	246,000	0.7	3.8	3.22
chilled	3	0.5	211,000	257,500	9.3	38.9	0.14
chilled	3	1.5	216,000	264,500	5.0	14.0	1.05
chilled	3	2.5	215,000	262,000	3.6	11.9	2.89
unchilled	5	0.5	216,000	265,000	2.1	3.8	1.05
unchilled	5	1.5	—	—	—	—	6.35
unchilled	5	2.5	213,000	242,000	0.7	3.3	3.54
unchilled	5	3.5	214,000	261,000	3.6	6.0	6.94
unchilled	5	4.5	216,000	258,000	1.4	4.4	4.33

Additional Microporosity Survey in Plate Castings*

Plate	Length	Distance from Plate End, in. 0	1	2	3	4	5
unchilled	1	0.68					
chilled	1	0.25					
unchilled	3	0.11	0.97	3.46	3.60*		
chilled	3	0.21	0.52	1.90	2.89*		
unchilled	5	0.04	2.04	6.47	6.53	5.89	4.33*
chilled	5		0.11	3.73	4.77	6.39	4.20

*All numbers except those with asterisks represent averages from two to four different plates. These data include additional castings over the castings reported above.

amined by careful microradiographic techniques. Figure 9 summarizes microporosity data obtained from 3 and 5 in. plates (chilled and unchilled). Each of the points on Fig. 9 is the average of data from two to four different microradiographs.

It should be remembered that "per cent microporosity" in Figs. 8 and 9 is greatly magnified quantity with respect to true volume per cent, due to the specialized experimental method employed in this study (point counting of microradiographs).

Figures 8 and 9 illustrate that it is extremely difficult to feed a steel casting to complete soundness. As thermal gradients are decreased from high values (several hundred degrees F/in.) the amount of fine microporosity increases gradually. The type of microporosity detectable by microradiography was eliminated only in regions of the casting 1) close to a casting edge or 2) in the vicinity of a chill. The increased thermal gradients near a riser reduced porosity but did not eliminate it.

This microporosity, while probably of little significance in steel castings at lower strength levels, is of major importance in determining ductility of metals at the higher strength levels studied herein.

Impact data (Charpy impact, –40 F) were obtained from each of the plate castings described. Results ranged from 6 to 13 ft-lb, and averaged 9 ft-lb. No correlation could be found between impact properties and microporosity.

Step Wedge Castings

A series of step wedge castings were prepared to further investigate the influence of solidification rate and casting section size on structure and properties (Fig. 10). Individual step wedges were cast in green sand and with various combinations of sand, chills and exothermic materials. Table 9 summarizes these treatments.

When a copper chill was used as mold material in the drag, and exothermic material in the cope, columnar grains grew throughout the entire 2 in. section (Fig. 11a). The exothermic material, burning at approximately the temperature of molten steel, acted as an essentially perfect insulator on the cope surface, and all solidification occurred from the drag face directionally upwards. When the drag was of sand and cope of exothermic material, thermal gradients were less steep; the columnar zone ceased to propagate earlier and a structure of coarse columnar grains plus equiaxed grains resulted (Fig. 11b).

When castings were poured without the exothermic material, using sand on all faces, solidification occurred from cope and drag at roughly similar rates, and structures were generally composed of both equiaxed and columnar grains. The lengths of the col-

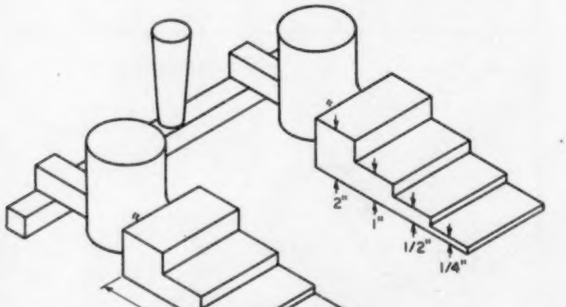


Fig. 10 — Design of step wedge castings.

umnar grains in each casting were dependent on the steepness of the thermal gradients introduced by the various treatments. Figure 12 shows typical sections from each of the four castings which were produced.

Values of elongation and reduction in area showed strong dependence on casting treatment and test bar location. In general, these properties were higher in castings, or portions of castings, which solidified under steeper thermal gradients. For example, the highest

TABLE 9 — STEP WEDGE CASTING TREATMENTS

Heat Number	Casting Number	Mold Surface Treatment: Top Surface	Mold Surface Treatment: Bottom Surface
E	1	green sand	green sand
E	2	green sand	copper chill
F	1	exothermic material one in. thickness	sand
F	2	exothermic material one in. thickness	copper chill

All castings were poured at 2850 F.

reduction in area obtained in the castings (35.4 per cent) was in a thin section (½-in. thick), solidified in a mold that had a copper chill drag and exothermic cope. Table 10 summarizes mechanical properties obtained.

In the step wedges as in other types of castings studied steep thermal gradients resulted in reduced microporosity, as well as in the differences noted above (columnar grains, improved ductility). For example, in one well fed region near a chill observations were 1) columnar grains, 2) low microporosity (essentially 0 per cent) and 3) high ductility (24.6 per cent reduction in area). In a location solidified under gradients that were much less steep, observations were 1) equiaxed grains, 2) high microporosity (1.60 per cent) and 3) low ductility (4.4 per cent reduction in area.

Structure, Microporosity and Mechanical Properties

Experimental results obtained in this study indicate the ductility of cast high strength steel is strongly de-

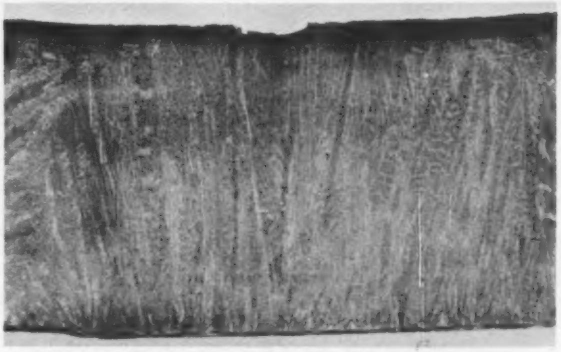


Fig. 11 — Macroetched vertical sections of step wedge castings, 2 in. thick sections. *A* (top) — Exothermic top surface, copper bottom surface. *B* (bottom) — Exothermic top surface, sand bottom surface.

pendent on casting structure. Test bars from columnar regions of castings are extremely ductile at the high strengths studied (even though the test bars are cut transversely across the columnar grains). Test bars from metal with equiaxed grains are much less ductile at the same strength level. In all castings produced, the incidence of microporosity was much higher in the equiaxed zone of the castings than in the region of columnar grains.

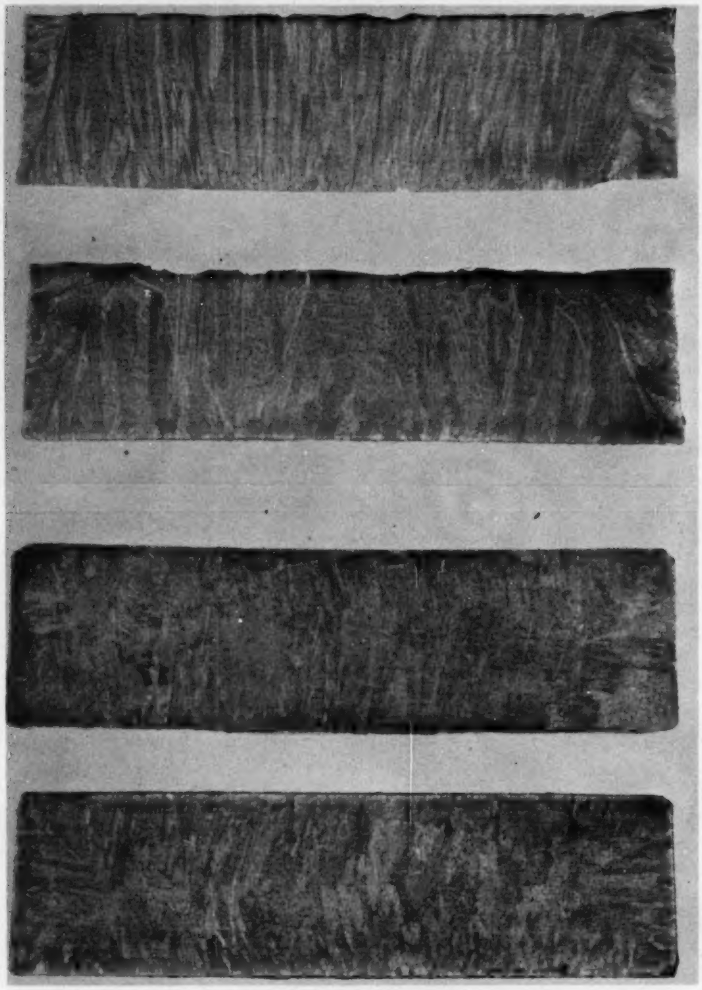
There appears to be no intrinsic reason why properties across columnar grains should be higher than those across equiaxed grains. The major cause of the lower properties in the equiaxed region is much more likely to be extrinsic to the grains themselves, and to be due to the increased amount of microporosity in

TABLE 10 — PROPERTIES OF STEP WEDGE CASTINGS

Heat	Mold Surface: cope	Mold Surface: drag	Section Thick., in.	Structure Description at location of test bar	Y.S. 0.2% offset lb/in.²	T.S. lb/in.²	Elong., %	Red. in area, %
E	sand	sand	0.5	coarse columnar	211,000	262,500	3.6	13.0
	sand	sand	1.0	coarse columnar	205,000	265,000	2.9	7.6
	sand	copper	1.0	fine columnar	225,000	270,000	4.3	17.6
F	exothermic	sand	0.5	coarse columnar	201,000	260,000	5.7	13.5
	exothermic	sand	1	coarse columnar	205,500	265,000	2.9	4.4
	exothermic	sand	2B*	coarse columnar	208,000	270,000	4.3	6.0
	exothermic	sand	2M*	equiaxed	—	202,700[1]	0.0	0.0
	exothermic	chill	0.5	fine columnar	217,000	266,000	10.0	35.4
	exothermic	chill	1	fine columnar	209,000	257,000[1]	0.0	0.0
	exothermic	chill	2B*	fine columnar	205,500	268,000	9.3	24.6
	exothermic	chill	2M*	fine columnar	212,000	269,000	9.3	27.5
	exothermic	chill	2T*	fine columnar	209,000	261,000	6.4	27.0

[1] Broke in the threads.

*Letter refers to location in 2-in. section — B = bottom, M = middle, T = top.



C — Exothermic top surface, copper bottom surface.

D — Exothermic top surface, sand bottom surface.

E — Sand top surface, copper bottom surface.

F — Sand top surface, sand bottom surface.

Fig. 12 — Macroetched vertical sections of step wedge castings, one in. thick sections.

this region. Other factors might also contribute, such as (primarily) a change in amount or shape of inclusions. However, in the relatively clean, high purity metal used for these studies, no significant change in inclusions could be found in the various castings.

Microporosity is lower in the columnar regions of the castings studied in this work, because the conditions which promote columnar grain formation are the same as those which lead to good directional solidification and feeding. Steep thermal gradients produce sound metal and at the same time favor columnar grain formation (especially in steel castings). When thermal gradients are shallow, equiaxed grains are more likely to form, the feeding is more restricted through the resultant narrow interdendritic channels. The interdendritic nature of microporosity is shown in Fig. 13, a microradiograph enlarged 50 ×. It is also shown in the typical microradiograph of Fig. 14.

The relationship of microporosity to ductility for all castings produced in this investigation is summarized in Fig. 15. Reduction in area is plotted because this quantity is most sensitive to changes in per cent porosity. When microporosity (as measured by the technique employed) is less than 0.50 per cent reduction in area, values of up to 40 per cent can be obtained. When microporosity is above one per cent, maximum reduction in area is about 10 per cent. With few exceptions, small amounts of microporosity are associated with good ductility, and large amounts of microporosity are associated with poor ductility.

CONCLUSIONS

A general discussion is presented on the effect of solidification variables on casting structure, and the relationship of casting structure to mechanical properties. This discussion is oriented towards steel castings.

A technique for preparing thin samples (approximately 0.005 in. thick) for microradiographic examination was developed and is described. Techniques of radiographing thin samples of steel to determine the amount of microporosity are discussed. The microradiographic technique was found especially valuable for measuring the amount of microporosity in steel castings.

A series of solid cylinder castings was poured to investigate the effect of solidification variables on structure. The presence of a chill on the bottom surface produced a columnar zone and a region relatively free

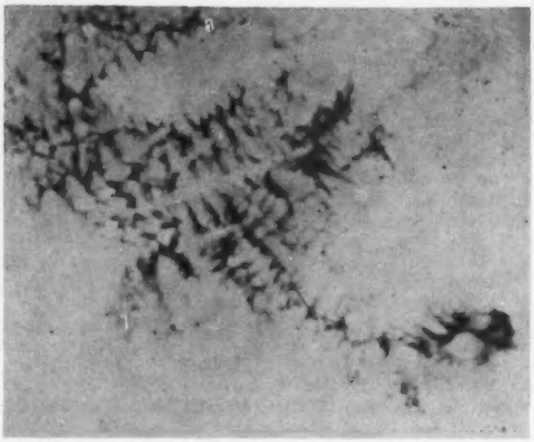


Fig. 13 — Microradiograph showing interdendritic nature of microporosity. Porosity is black. 50 ×.

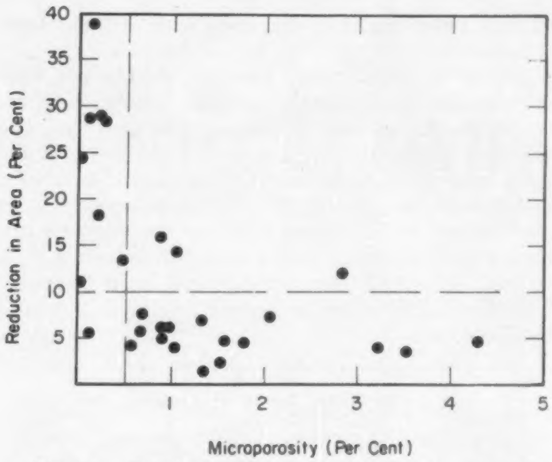


Fig. 15 — Relationship between reduction in area and microporosity.

of microporosity. Mechanical properties from the columnar region, as compared with typical properties from equiaxed regions of the cylinder castings were:

Region	Yield Strength, psi	Tensile Strength, psi	Elong., %	Red. in area, %	Microporosity
Columnar Chill Zone (transverse to grains)	218,000	270,000	10.7	27.0	0.38
Typical, Equiaxed Zone	218,000	272,500	5.0	7.1	1.17

A steel rod placed in the riser of a solid, cylindrical casting resulted in substantial grain refinement of the equiaxed zone of crystals. Vibrating the chill rod did not increase the refinement above that noted with the chill rod alone. Gravity settling of crystals formed in the region near the chill rod appears to be the major grain refining mechanism. There was no improvement in mechanical properties detected as a result of the grain refinement achieved.

A "denucleating" effect was observed in a casting that was gated through a vibrating steel box.

A series of plate castings (½-in. thick) were produced to study the effect of plate length and chilling on microporosity and mechanical properties. Values as high as 260,000 psi ultimate tensile strength, 220,000 psi yield strength and 40 per cent reduction in area were obtained near a chill (where microporosity was essentially zero). Microporosity was found to increase 1) if the plate was not chilled and 2) with increasing distance from the plate end (chilled or unchilled). Mechanical properties, particularly reduction

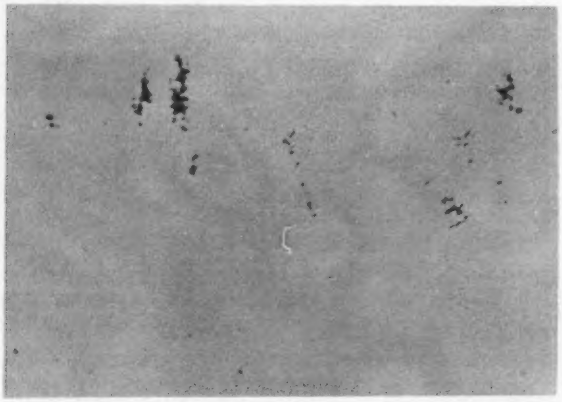
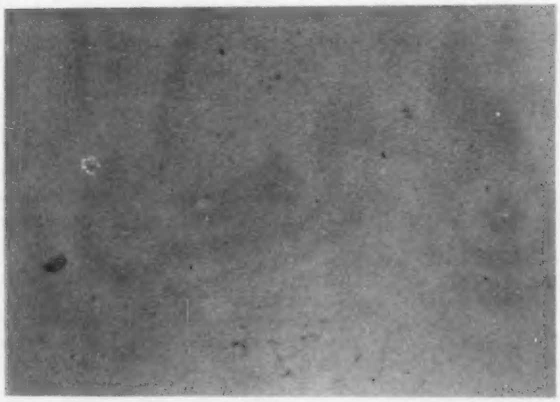


Fig. 14 — Typical microradiographs. Microporosity is black. Approx. 12 ×. *A* (top, left) — 3.50 per cent microporosity. *B* (bottom, left) — 0.85 per cent microporosity. *C* (below) — 0.20 per cent microporosity.



in area and elongation, decreased with increasing microporosity.

Effects of solidification rate and section size were investigated in step wedge castings. This series of experiments showed that castings could be produced with excellent mechanical properties throughout a 2 in. thick section, provided steep thermal gradients were maintained. By the use of exothermic materials on one surface and a copper chill on the opposite surface, columnar grains were grown throughout a 2 in. section. Properties from one such casting as compared with those from a similar casting solidified in a sand mold are:

Region	Yield Strength, psi	Tensile Strength, psi	Elong., %	Red. in area, %	Micro-porosity
Columnar zone (chill drag and exothermic cope)	205,500	268,000	9.3	24.6	0.00
Equiaxed zone, sand cope and drag	205,000	265,000	2.9	7.6	1.60

A correlation was made between microporosity existing in various locations of all the test castings examined, and the ductility of material from these locations. When microporosity is less than 0.50 per cent (this percentage is not a true volume per cent, but a magnified volume per cent determined by the special technique employed), then values of up to 40 per cent reduction in area can be achieved in high purity. A.I.S.I. 4340 steel heat treated to a strength level of 250,000 to 300,000 lb/sq in.

A relationship was found to exist between the as-cast structure of steel castings and susceptibility to microporosity. Substantially more porosity was found in equiaxed areas of steel castings than in columnar areas. It is shown herein that conditions for the formation of a columnar zone (steep temperature gradients) are identical to the conditions for excellent directional solidification and feeding.

ACKNOWLEDGMENT

This work was carried out under Ordnance Corps Contract No. DA-19-020-505-ORD-4511, through Rodman Laboratory, Watertown Arsenal. The authors wish to acknowledge particular appreciation to Mr. Paul Ahearn and Mr. John Zotos for helpful suggestions during the course of the work.

Acknowledgment is also due to Mr. Charles Rowe and Mr. Ivan M. Schmidt for their assistance in the course of the investigation, and to the foundry personnel under supervision of Mr. Edwin Backman. Illustrations were prepared by Mr. George E. Schmidt.

REFERENCES

1. Foundry Section, Metal Processing Div., Dept. of Met., Massachusetts Institute of Technology, "Investigation of Solidification on High Strength Steel Castings under Simulated Production Conditions," Final Report, Depart. of the Army, Ordnance Corps., Contract Number DA-19-020-505-ORD-4511 (July 1, 1958).
2. Flemings, M. C., Green, R. and Taylor, H. F., "Structural Variables Influencing Mechanical Properties of High Strength Cast Steels; A Progress Report," AFS Transactions, *vol. 67* (1959).
3. Foundry Section, Metal Processing Div., Dept. of Met., Massachusetts Institute of Technology, "Investigation of Solidification of High Strength Steel Castings under Simulated Production Conditions," Final Report, Depart. of the Army, Ordnance Corps., Contract Number DA-19-020-505-ORD-4511 (July 1, 1958).
4. Walther, W. D., Adams, C. M. and Taylor, H. F., "Effect of Casting Fiber on Mechanical Properties of Al-4% Cu Alloys," AFS Transactions, *vol. 61*, pp. 664-673 (1953).
5. Northcott, H. L. "Mechanical Properties of Metals in the Cast Condition," *Institute of Metals, 68*, p. 189 (1942).
6. Northcott, H. L., "Influence of Turbulence on the Structure and Properties of Steel Ingots," *Jl. Iron and Steel Institute, 143*, pp. 49-88 (1941).
7. Reynolds, J. A. and Preece, A., "Metal and Metal Research on Steel Castings, Part I: Solidification Mechanism," *Foundry Trade Journal, 99*, pp. 31-38 (1955).
8. Jackson, W. S., "Some Features of the Metallurgical Properties of Steel Castings," *British Foundryman, 50*, pp. 211-219 (April 1957).
9. Larson, H. R., Lloyd, H. W. and Herlihy, F. B., "Comparison of X-ray Quality and Tensile Properties in Cast High Strength Steel," AFS Transactions, *vol. 67* (1959).
10. Cibula, A., "The Mechanism of Grain Refinement of Sand Casting in Al Alloy," *Journal of Institute of Metals, 76*, p. 321 (1949-1950).
11. Gary, "The Effects of Gravity on the Solidification of Steel," *Journal of Iron and Steel Institute, 182*, pp. 366-374 (1956).
12. Hucke, E. E., Flemings, M. C., Adams, C. M. and Taylor, H. F., "Metal Solidification in a Flowing Stream," AFS Transactions, *vol. 64*, p. 636 (1956).
13. Northcott, H. L., "The Influence of Alloying Elements on the Crystallization of Copper," *Journal Institute of Metals, 62-101* (1958); and *658*, p. 173 (1939).
14. Chalmers, B., "Effect of Impurities and Imperfections on Crystal Growth," *Impurities and Imperfections*, A.S.M., p. 84 (1954).
15. Tiller, W. A. and Rutter, J. W., "The Effect of Growth Conditions Upon the Solidification of a Binary Alloy," *Canadian Journal of Physics, 34*, p. 96 (1956).
16. Walker, J. L., "Structure of Ingots and Castings," *Liquid Metals and Solidification*. A.S.M., p. 319 (1958).
17. Hucke, E. E., Flemings, M. C., Adams, C. M. and Taylor, H. F., "The Degeneration of Freezing Plane Interfaces in a Controlled Solidification System," *Internation Symposium on the physical Chemistry of Process Metallurgy*, A.I.M.E., Pittsburgh (1959).
18. Wagner, C., "Theoretical Analysis of Diffusion of Solutes during the Solidification of Alloys," *A.I.M.E. Transactions, 200*, p. 154 (1954).
19. Schiel, E., "Die Entstehung des Gussgefuges momogener Metalle," *Zeit. Fur Metallrunde, 29*, pp. 404-409 (1937). Abridged Translation in *Metal Treatment, 4*, pp. 11-14 (1938).
20. Tammann, G., *Aggregatzustande* 1. Voss, Leipzig, p. 223 (1922).
21. Genders, R., "The Interpretation of the Macrostructure of Cast Metals," *Journal Institute of Metals, 35*, p. 259 (1926).
22. Freedman, A. M. and Wallace, J. F., "The Influence of Vibration on Solidfying Metals," AFS Transactions, *vol. 65*, p. 578 (1957); "Vibrating Strength into Metals," Modern Castings *vol. 31*, p. 64 (April 1957).
23. Garlick, R. G. and Wallace, J. F., "Grain Refinement of Solidifying Metals by Vibrations," AFS Transactions, *vol. 67*, p. 366 (1959).
24. Papapetrou A., "Untersuchungen uber Dendritisches Wachstum von Kristallen," *Zeit Fur Kristabbagraphie, 92*, p. 89 (1935).
25. Trillat, J. S., "Metallurgical Aspects of Microradiography," *Met. Reviews, 1*, pp. 3-30 (1956).
26. Homes and Gouzou, *Revue Met., 48*. p. 251 (1951).
27. Engstrom, A. and Lindstrom, B., "The Properties of Fine-Grained Plate Emulsion for Microradiography," *Acta Radiologica, 35*, pp. 33-44 (Jan. 1951).
28. Michael, A. and Bever, M. B., "Solidification of Aluminum Rich Aluminum-Copper Alloys," *A.I.M.E. Transactions, 200*, p. 47 (1954).
29. Sharpe, R. S., "The Microradiography of Metals, its Advantages and Limitations," *X-ray Microscopy and Microradiography*, Cosslett, U. E., Engstrom A. and Pattee, H. H., Academie Press, N. Y. pp. 590-602 (1957).
30. Briggs C. W., "The Solidification of Steel Castings," *Steel Founders Society of America*, Research Report No. 30, Cleveland (Sept. 1953).

DUST COLLECTOR REVIEW

by David G. Stephan

ABSTRACT

Selection criteria for dust and mist collection equipment are outlined. From these it is seen that a wide variety of collector types is necessary and that no single type is appropriate for all applications. The six general categories of collection equipment available commercially (settling chambers, inertial separators, cyclones, filters, electrical precipitators and scrubbers) are discussed in terms of principles of operation, general descriptions, advantages and limitations. Included is a table of approximate collector characteristics which lists cost, smallest particle size collected, pressure drop and power requirement for each collector type.

INTRODUCTION

In the foundry industry, dust collectors have been utilized for many years as standard equipment on a number of operations. Rare is the case in which casting cleaning, shakeout or grinding operations do not have a dust collector of some type as an integral part of the process. Familiarity with this equipment gives the foundryman an excellent background for understanding the principles, advantages and limitations of the various types of dust collection equipment. This asset may well lead to direct financial savings as the need for expanded dust control activity increases over the coming years.

This need is already apparent in a number of localities, but with the growing public awareness of air pollution control ordinances requiring more comprehensive and more efficient dust and fume elimination are a virtual certainty during the 1960s.

COLLECTOR USES

There are a number of reasons for which collection equipment is used. Obviously collectors are, in many cases, simply a component of a process, without which the process could not operate. Examples are the collection of material being pneumatically conveyed, the collection of a product such as zinc oxide, carbon black or dehydrated milk or the recovery of reusable materials such as nonferrous grinding dusts.

In other cases collectors are used to reduce equipment maintenance, e.g., the oil bath air cleaner on a car, to improve product quality, the cleaning of ventilation air to a photographic film manufacturing area or to prevent physical damage to the plant or equipment or the removal of acid mists or collection of fumes causing damage to automobile finishes. Each of these instances presents some measure of positive economic justification for installing and using control equipment. Also, there are applications necessary because of either moral or legal considerations.

Here are included the eradication of safety or health hazards, e.g., the collection of siliceous particulates or combustible dusts and the elimination of nuisances. In some cases the economic justifications for such installations are obvious, but in others one must appreciate his obligations toward maintaining the health and welfare of his employees, his neighbors and his community.

COLLECTOR SELECTION AND DESIGN

For the intelligent selection or design of dust collection equipment many factors must be considered. These may be outlined:

1. Particulate characteristics.
   a. Particle-size distribution. Particle diameters are usually given in microns (1 micron = $\frac{1}{25,400}$ in.).
   b. Particle shape.
   c. Particle density.
   d. Physico-chemical properties.
      1) Hygroscopicity.
      2) Agglomerating tendency.
      3) Corrosiveness.
      4) "Stickiness."
      5) Flowability.
      6) Electrical conductivity.
      7) Flammability.
      8) Toxicity.
2. Carrier gas characteristics.
   a. Temperature.
   b. Pressure.
   c. Physical properties.
      1) Humidity.
      2) Density.
      3) Viscosity.
      4) Electrical conductivity.
   d. Chemical properties.
      1) Corrosiveness.
      2) Flammability.
      3) Toxicity.

D. G. STEPHAN is Senior Sanitary Engr., U.S. Public Health Service, Dept. of Health, Education and Welfare, Engrg. Rsch. and Dev. Unit, Air Pollution Engrg. Rsch., Robert A. Taft Engrg. Center, Cincinnati, Ohio.

3. Process factors.
   a. Volumetric flow rate.
   b. Constancy or variability of gas flow.
   c. Particulate concentration, usually given in grains/cu ft (1 grain = $\frac{1}{7000}$ lb).
   d. Allowable pressure drop.
   e. Product quality requirements.
   f. Required collection efficiency. The requirement may be based upon:
      1) Value of material being collected.
      2) Nuisance or damage potential of the material.
      3) Physical location of the exhaust.
      4) Geographical location, i.e., air pollution susceptibility of the area.
      5) Applicable code or ordinances (consider anticipated future legislation).
4. Operational factors.
   a. Ease of maintenance.
   b. Need for continuity of operation.
5. Constructional factors.
   a. Available floorspace.
   b. Headroom limitations.
   c. Material limitations imposed by temperature, pressure or corrosiveness of exhaust stream.
6. Economic factors.
   a. Installation cost.
   b. Operating cost.
   c. Maintenance cost.

When it is realized that all of the above factors can bear on the choice of the proper dust collector for a given service, it is easy to see that a wide variety of collectors is needed and that no single collector or type of collector is appropriate for all applications. Such a variety is available commercially, and it would be impractical here to describe each in detail. However, the many types and designs may be conveniently grouped into six categories–settling chambers, inertial separators, cyclones, filters, electrical precipitators and scrubbers. The principles of operation, the general physical descriptions, the advantages and the limitations of each category are given in the following paragraphs.

SETTLING CHAMBERS

The settling chamber is the simplest type of dust collector. It consists of an enclosure in which the velocity of the dust-laden stream is reduced to allow suspended particles to settle out by gravity and, once settled out, not to be re-entrained. Physically, settling chambers may range from a simple expanded duct section to an inlet hopper or inlet plenum for some other piece of equipment, or to a specially constructed chamber having tapered inlet and outlet sections, internal guide vanes or even a large number of closely spaced horizontal shelves.

They are usually "homemade," and often are used as precleaners to reduce the load of large particulates to a second dust collector following in series. Simple settling chambers cannot be expected to provide adequate collection efficiencies for particles in the subsieve range ($<$40 microns). Multiple tray units (Fig. 1), however, may be able to remove particles as small as 10 to 20 microns if properly designed. Collection efficiency is directly proportional to the total projected horizontal area within the chamber.

Hence, the use of horizontal shelves increases overall efficiency, but vertical baffles, other than those for straightening flow, are not, in general, of value. Efficiency is independent of chamber height, but obviously the unit should be sufficiently high to provide velocities low enough to prevent re-entrainment (normally $<$10 ft/sec).

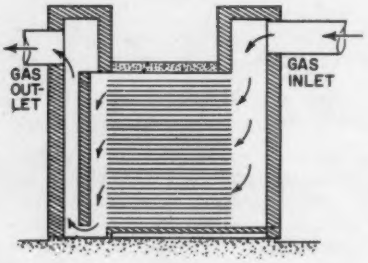


Fig. 1 — Multiple tray settling chamber.

Settling chambers are of simple construction and low cost, and pressure loss is often negligible. Maintenance requirements are minimal, and material is collected dry and can be disposed of continuously. Temperature and pressure limitations are imposed only by the materials of construction. On the other hand, equipment size is large with efficiency decreasing with diminishing particle size and low efficiencies expected for small particles. Also, in the case of multiple-shelf units, cleaning difficulties and warping tendencies may be experienced, and plugging may occur at inlet concentrations above 1-5 grains/cu ft.

INERTIAL SEPARATORS

In this category collectors utilize particulate inertia to cause the particles to migrate toward a collecting surface. Both simple inertial or impaction separators and cyclonic separators actually should be included here. However, cyclones will be discussed separately because of their widespread applicability and importance in dust control.

Inertial separators employ single or multiple changes in flow direction to cause particles to cross fluid streamlines and to concentrate or to impinge on a collecting surface. Performance of these devices is analyzed in terms of target efficiencies (fraction of particles in the fluid volume swept by an obstructing body which are collected by the body). Generally it may be said that efficiency increases with increasing particle size and density and with increasing fluid velocity. Efficiency decreases as the size of the obstructing body and as viscosity of the fluid increase.

Most inertial separators may be classified in one of four general types. One type, the baffle chamber, is an enclosure in which the gas stream is forced to follow a tortuous path around staggered plates. The gas, therefore, undergoes a series of sudden changes of direction causing suspended particles to impinge on the baffles. Such units are often combination inertial sep-

arators and settling chambers. The pressure drop (0.5 to 1.5 in. H_2O) is greater than for a simple settling chamber. The particle size capable of being collected is on the order of 20 microns rather than 40. Collected material is normally cleaned from the baffles by mechanical rapping or by a flowing water film. These units can be used in high-temperature service and for mist separation, but they cannot handle tacky materials. Also, abrasive wear can sometimes cause high maintenance costs.

Orifice Impaction Collector

The second type is the orifice impaction collector, popular as a mist separator. Here, two successive sets of orifice plates are installed in series in the gas stream. The first set has staggered openings from one plate to another which promote agglomeration of fine liquid particles. The second set of plates, at which collection occurs, contains aligned orifices. This type of collector is highly efficient for liquid aerosols larger than 2-3 microns because of the agglomerating feature. It is normally operated at orifice velocities on the order of 50-100 ft/sec, giving pressure drops of approximately 1-3 in. H_2O.

Louver chambers comprise the third type of inertial collector. In these devices (Fig. 2), a series of closely spaced louvers are set at an angle to the air stream such that particles strike the louvers, rebound and travel toward the outlet end in increasing concentrations. The concentrated dust stream is then led off through a secondary air circuit to a separate collector. The louver chamber is, therefore, a particulate concentrator rather than an actual collector.

The efficiency of this type of inertial collector depends on the louver spacing and the gas velocity. Generally, particles larger than 10-15 microns can be collected satisfactorily at pressure drops near 1 in. H_2O. The principle advantages are simplicity, low cost and high-temperature applicability. Chief disadvantages are a tendency to plug, excessive abrasive wear and inability to handle tacky materials.

The fourth type of inertial separator is the so-called high-velocity gas-reversal chamber. In this type the gas stream is caused to change direction abruptly, thereby projecting large particulates into a dead air space from which they are removed by gravity settling. This equipment, which is simple and low cost and may be appreciably smaller than simple settling chambers, gives adequate efficiencies only for particles larger than 40-50 microns.

CYCLONES

Cyclones are probably the most widely used of all dust collectors. They consist of a cylindrical or conical chamber with a tangential entry and axial discharge. The inlet gas stream spirals downward along the wall and then upward and out through the center. Suspended particles are projected to the wall by centrifugal force where they fall by gravity toward the bottom of the unit.

There are three general types of cyclonic collectors—the simple cyclone, high-efficiency multiple units and mechanical cyclones. Simple cyclones (Fig. 3), are from one to as much as 15 or 20 ft in diameter. Inlet velocities are usually near 50 ft/sec, and pressure drops range from 0.5 to 3 in. H_2O. Simple cyclones may normally be expected to provide efficient collection of particles larger than 15 to 20 microns.

Since cyclone diameter is the design factor having the greatest effect on efficiency, recent trends have

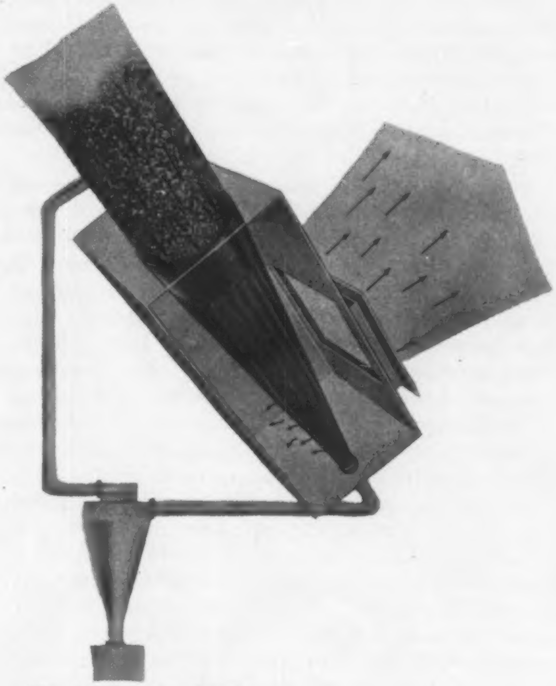


Fig. 2 — Louver chamber.

Fig. 3 — Simple cyclones.

been toward the second type—the high-efficiency multiple units, in which unit diameter is smaller and multiple cyclones are utilized in parallel (Fig. 4). Pressure drops for these collectors may be in the range of 2 to 10 in. H_2O, but this type of design can extend efficient collection to particles as small as 5 to 10 microns.

Advantages of these first two cyclone types include low initial cost, relatively simple construction, dry and continuous disposal of collected material, low to moderate pressure loss and relatively low maintenance costs where no highly abrasive materials are present. In addition, these units can be used satisfactorily at high temperature or high pressure, as long as appropriate materials of construction are used. Disadvantages are low efficiency for particles below 15 to 20 microns for simple cyclones and 5 to 10 microns for multiple units and susceptibility to severe abrasive deterioration in certain cases.

Mechanical cyclones, or dry centrifugal collectors (Fig. 5), are identical in principle to the cyclonic collectors previously discussed but they contain one or more motor-driven rotating elements. In such units, the particulates are concentrated at the periphery where they are removed through an annular slot or skimmer. The chief advantage of these units lies in their compactness and low pressure loss (pressure gains may even be found with some units).

Collection efficiencies are roughly the same as for high-efficiency multiple cyclones. Their major limitation is a tendency for solids to build up on the rotating elements causing plugging or rotor unbalance. Temperature limitations also exist because of the presence of bearings, seals, etc.

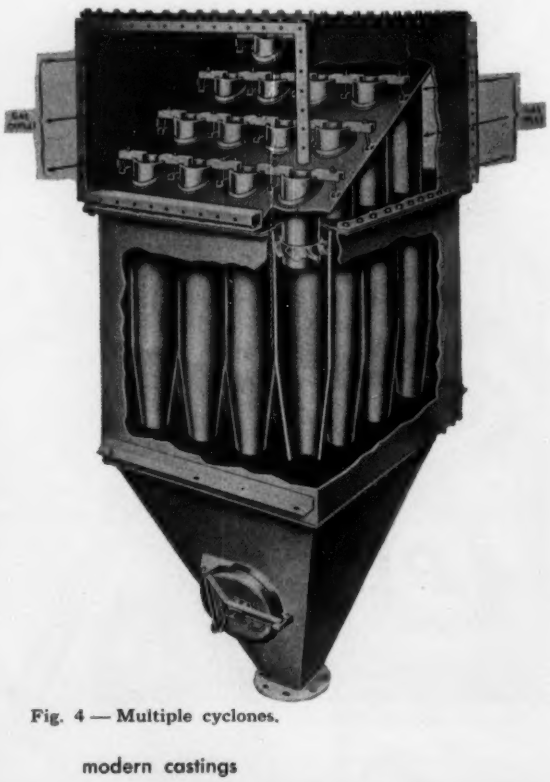


Fig. 4 — Multiple cyclones.

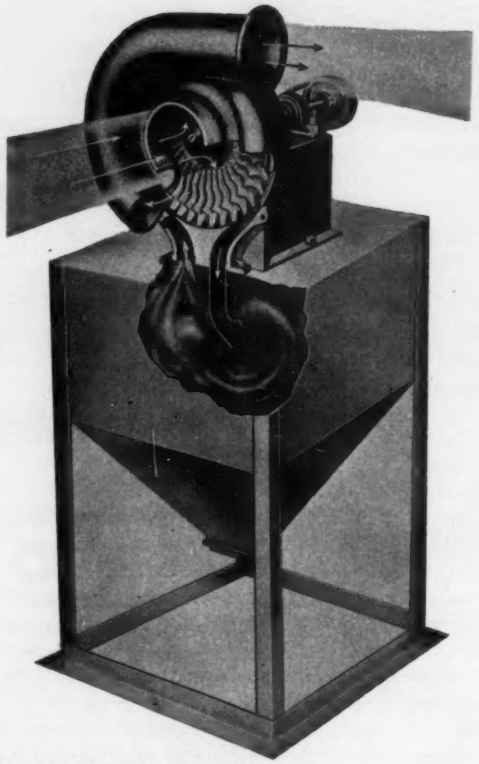


Fig. 5 — Mechanical cyclone.

FILTERS

Gas filters may be divided into two basic types, the fabric filter and the deep bed filter. The fabric filter is, at present, by far the more important of the two for industrial dust control. The basic difference between the two types lies in the mechanisms by which particle deposition occurs. In a fabric filter, the fabric serves primarily as a filter support, and particulate collection is accomplished during the passage of the gas stream through the previously collected dust cake. Actual "sieving" is a major collecting mechanism.

A deep bed filter, on the other hand, consists of a loosely packed mat of fibrous materials which is, in reality, an inertial separator in which the collecting elements are the fibers themselves. Deep bed filters are widely used as domestic furnace filters and on air conditioning systems, but they are not common where high grain loadings are encountered.

Fabric filters offer high efficiency collection of particles as small as 0.1 micron or less. The most common type is the shaken baghouse in which mechanical or pneumatic shakers are used periodically to clean the collected dust cake from vertically suspended tubular bags (Fig. 6). The dust stream enters the collector near the bottom through a combination inlet plenum-dust hopper and then passes upward and outward through the tubes forming a dust cake over their internal surfaces.

Gas velocities through the fabric are normally between 1 and 4 ft/min and maximum pressure drops

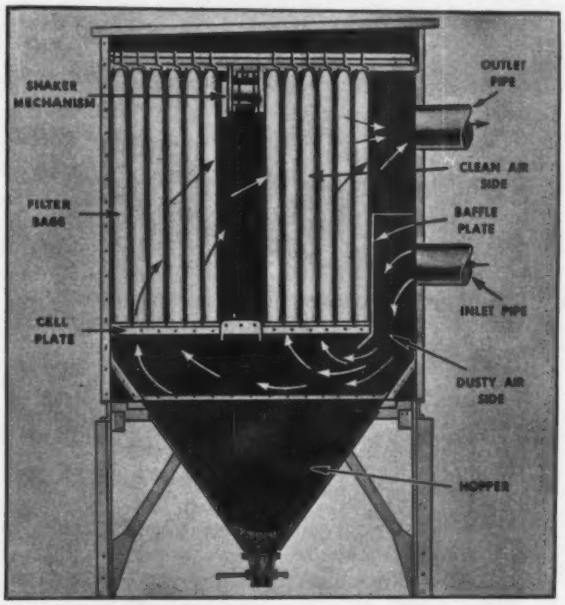


Fig. 6 — Baghouse filter.

are usually held to 4 to 6 in. H_2O. Air flow must be stopped when the filters are cleaned but multi-compartmented, automatically programmed equipment may be used when continuous service is desired. Woven fabrics are the usual filter media in this type of collector, with cotton sateen the cheapest and most commonly used. Materials used for higher temperature service or to resist chemically active gases include wool, nylon, dacron, orlon and glass.

Normal temperature limits for these materials are: cotton, 180 F; wool, 220 F; nylon, 225 F; orlon and dacron, 275 to 300 F and glass, 450 to 500 F. Baghouse inlet temperatures, of course, may be somewhat higher than these limits.

Reverse Jet Collector

In addition to mechanical shaking, other filter cleaning techniques are sometimes used. They include reverse jets, collapse cleaning, air pulsing, sonic cleaning and combinations of these methods. In a reverse jet unit (Fig. 7) felts serve as the filter media, and cake removal is accomplished by a high velocity jet of compressed air issuing from a narrow slot on a closely fitted or spring-loaded hollow ring which traverses the entire length of the filter. Filter velocities up to 15 or 20 ft/min are sometimes possible. This means that these units can be appreciably smaller than shaken baghouses of the same volumetric capacity.

Cleaning is carried out continously or semicontinuously while air flow continues yielding a relatively constant pressure drop and, therefore, relatively constant flow rate rather than the cyclic fluctuations in flow inherent with periodic cleaning. Disadvantages of reverse jet units are higher purchase and maintenance costs, lower temperature limits ($\sim$300 F), and a tendency towards gradual blinding of the felt media with fine dusts.

In the last several years, cleaning by collapsing tubular filters with a slight reverse pressurization has become popular on high temperature units using glass bags. This "single stroke" cleaning appears to decrease filter wear appreciably, an important matter considering the relatively poor wear-resistance of glass fabrics. The technique, however, may not be satisfactory where "hard to clean" dust-fabric combinations exist.

Several manufacturers are also supplying filters in which cleaning is accomplished by air pulsing, i.e., by directing short bursts of high-pressure air into the filter bags and "popping" them open. With this design, the bags are mounted over wire frames and the gas to be filtered flows from the outside to the inside of the bags. Recently, tubular baghouses have become available which combine collapse cleaning and air pulsing, and, within the last year, filters have come on the market in which low frequency sonic energy is used for cleaning.

Cloth Envelope Collector

Differing in geometry from the tubular filter is the cloth envelope type (Fig. 8). Flat filter bags, 1 to 2 in. thick and roughly 2 by 4 ft in size, are mounted over wire frames from a vertical tube sheet. The filter cake is formed on the external surface of these bags and is removed by mechanical rapping. These filters can be cleaned continuously without shutting off the air flow to the unit when specially designed cleaning equipment is employed to supply a slight reverse air flow sequentially to the filter bags during rapping.

Advantages of fabric filters are high collection efficiency for all particle sizes even when variable flow rates and variable inlet concentrations exist, relatively simple construction, moderate cost, dry collection and nominal power consumption. Disadvan-

Fig. 7 — Reverse jet filter.

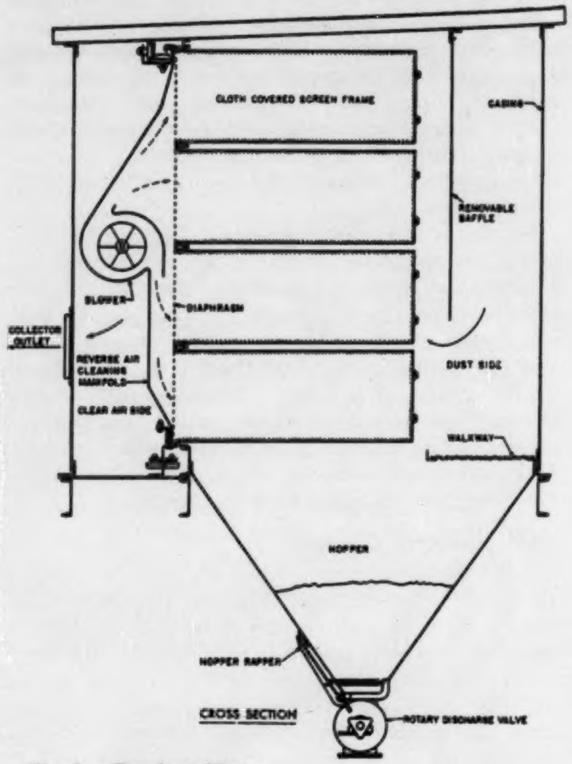


Fig. 8 — Envelope filter.

tages relate to size, temperature and humidity limitations and maintenance costs.

With respect to temperature limitations of this and other types of collectors, it is well to discuss gas cooling briefly. Three methods can be used:

1) Cooling by radiation and convection.
2) Cooling by evaporation.
3) Cooling by dilution with ambient air.

The dilution method increases the volume of gas to be filtered, and is normally used only in conjunction with one of the first two methods. Radiation and convection cooling generally requires a greater initial capital outlay than evaporative cooling, but operation is less costly. Evaporative coolers, on the other hand, are usually cheaper to install but require a continuous supply of cooling water and have higher maintenance costs due to wet corrosion. Evaporative cooling is the most popular technique in the foundries of the Los Angeles area where fabric filters have found wide usage. When using evaporative cooling, the biggest concern is with overhumidification and resultant condensation problems.

ELECTRICAL PRECIPITATORS

High-efficiency collection of particles 0.1 micron in diameter and even smaller under severe operating conditions is offered by the electrical precipitator (Fig. 9). Particle deposition is accomplished by passing the gas stream between electrodes across which a high voltage is impressed. The discharge electrode has a much smaller radius of curvature than the collecting electrode and, as a result, corona discharge. A powerful ionizing field is established near the discharge electrode; potentials as high as 100,000 volts are used.

Particles passing through the ionizing field become charged and subsequently migrate to the collecting electrode. Once deposited, they lose their charge and are removed either by mechanical vibration or by washing.

Both single-stage and two-stage precipitators are in use as particulate collectors. In the two-stage unit, ionization is achieved in the first stage and particle collection in the second. This kind of precipitator

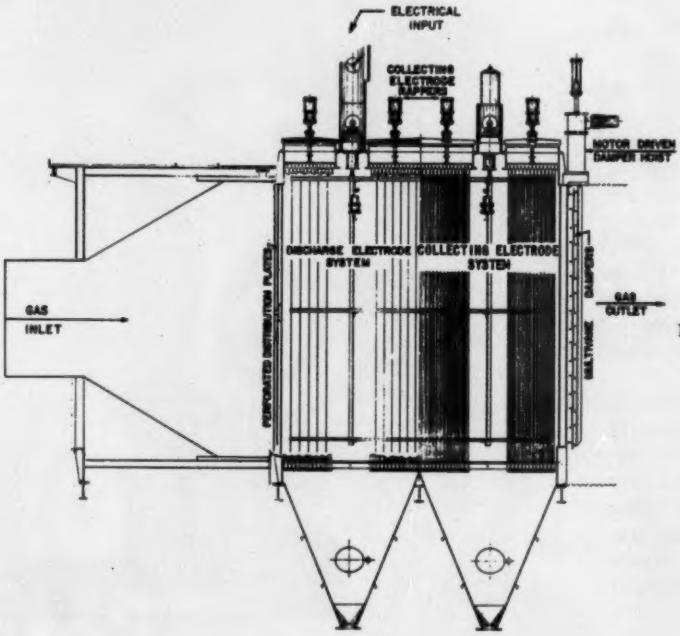


Fig. 9 — Electrical precipitator.

is rarely used for industrial dust collection, but is employed most often in air conditioning installations.

With the single-stage precipitators, ionization and particle collection occur simultaneously at the same set of electrodes. In plate-type precipitators, the collecting electrodes consist of parallel plates either of solid or expanded metal closely spaced rows of rods, chains or wire or specially formed shapes. In the pipe-type precipitator, the collecting electrodes are formed by a nest of parallel tubes which may be square, round or octagonal. In each case, discharge electrodes are wires or small, twisted rods, suspended vertically either midway between the parallel collecting electrodes of the plate-type unit or axially along the length of the pipes of the pipe-type unit.

Electrode cleaning is normally carried out while gas flow continues, and is accomplished by periodic or continuous mechanical rapping or by a flowing liquid film. Electrodes may range from 5 to 20 ft in length, and electrode spacing is usually 3 to 8 in.

Potential Efficiency

The potential collection efficiency is greatly affected by the electrical resistivity of the particulate matter. Relatively small changes in resistivity can cause appreciable differences in operating characteristics of the precipitator. High-resistivity material results in a reduced potential gradient across the gas space and in back ionization at the collecting electrode. Both of these factors contribute to reduced efficiency.

The induced lowering of resistivity of the particulate matter being collected is called conditioning. This may be accomplished by humidification, temperature control or by the addition of chemical agents, notably ammonia, sulfuric acid or SO_3.

Gas velocities average 3 to 10 ft/sec but, obviously, as velocity increases retention time decreases and this leads to reduced efficiency. A common design deficiency is unequal flow distribution. This matter is so important that baffles, guide vanes or distributor plates are often used to improve the flow pattern.

The chief advantages of the precipitator are its high efficiency collection under varying and quite severe conditions, high-temperature applicability, low maintenance and operating costs and low pressure drop. Disadvantages include high initial cost, large size and possible explosion hazards with flammable materials. Of great importance is the logarithmic relationship of outlet concentration to the size of the equipment. That is, a precipitator giving 90 per cent efficiency must be doubled in size to give 99 per cent efficiency and tripled to give 99.9 per cent.

SCRUBBERS

In a general sense, "scrubbers" includes gas absorption equipment as well as particulate collectors. However, in current air pollution control usage the term generally applies to devices which utilize a liquid to achieve or assist in the removal of solid or liquid dispersoids from a carrier gas. Water is by far the most common liquid employed, but in certain special cases other liquids have been used.

Scrubbers are constructed in such a wide variety of designs that no single type can be considered as representative. Some scrubbers are simply previously existing dry-type collectors which have been modified to allow the introduction of a liquid phase; other units are specifically designed as wet collectors.

Particle collection is generally achieved by one of four mechanisms:

1) Particles may be made to impinge on a liquid surface.
2) Particles may be allowed to diffuse to a liquid surface.
3) Liquid may condense directly on individual particles, increasing their size and thereby their ease of collection.
4) Carrier gas may be partitioned into a number of small individual elements within which particles are collected by Brownian* diffusion and gravity settling.

According to theory, collection by the impingement mechanism should increase in efficiency as collecting droplet size decreases. This is true to a point, but as spray droplet size falls below 30-50 microns impingement efficiencies decrease rapidly, since smaller droplets are accelerated almost instantaneously to the carrier gas velocity and then no relative velocity exists between the droplets and the particles to be collected. Impingement is most effective for particles larger than 5 microns. For finer particles, the diffusional mechanism becomes of increasing importance.

Condensation Nuclei

Condensation occurs when the carrier gas is cooled through its dew point. Submicron particles serve as condensation nuclei. As a result effective particle size is increased, thereby enhancing inertial collection. This mechanism, however, is generally effective only where hot gases containing relatively low loadings are concerned. Gas partitioning is achieved by dispersing the carrier gas into small volumetric increments, i.e., small bubbles or foam. Here, efficiency of collection increases as the size of the incremental gas volumes decreases.

In most practical applications, the particles to be collected cover a range of sizes and more than one mechanism plays a part. Regardless of the mechanism, however, high efficiencies are favored by large interfacial areas, and, therefore, small droplet size is advantageous. Also, current thinking is that properly designed scrubbers will be highly efficient collectors for any particle size if the power input to the scrubber is high enough.

Power may be consumed by high pressure atomization of the liquid phase, by high velocity jetting of the liquid, by high carrier gas velocities or by mechanical energy input to rotating elements. Available commercial scrubbers offer high efficiency collection of particles larger than about 5 microns at relatively low power input, of particles in the 2- to 5-micron range at moderate power input and of particles down to 1 micron or below with high power consumption.

Scrubbers may be grouped roughly in seven design

*Dr. Robert Brown first demonstrated the rapid vibratory movement exhibited by microscopic particles in about 1827.

types. The first, and most common, is the spray tower. These units are simply chambers in which the carrier gas passes through banks of sprays positioned either parallel or normal to the gas stream. The sprays are followed by some type of inertial collector which serves as a mist entrainment separator. A common example of this type collector is the cupola wet-cap (Fig. 10). For such units, water consumption runs about ½ to 2 gallons/1000 cu ft of gas. Pressure drops are usually in the range of 0.1 to 0.5 in. H_2O.

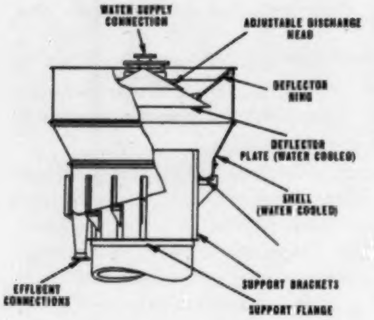


Fig. 10 — Cupola wet cap.

Jet Scrubber

In the jet scrubber (Fig. 11), a high velocity water jet is directed axially into the throat of a venturi section. This is followed by an entrainment separator, usually a simple gas-reversal chamber. These units serve as collectors and also may act as aspirating-type air movers. Pressure gains up to as much as 7 or 8 in. H_2O may be developed. Water consumption is high, often in the range of 50 to 100 gallons/1000 cu ft. Of somewhat similar design is the venturi scrubber (Fig. 12).

In this scrubber, it is the gas phase which is passed through the venturi throat at high velocity (200-300 ft/sec). Water sprays are injected just preceding the throat, and the entrained droplets are subsequently removed by a cyclonic separator. For these units, water consumption is normally 3 to 10 gallons/1000 cu ft, and pressure drops range from 10 to 15 H_2O. For collection of fine fume, for example, pressure losses of 30-35 in. H_2O may be required.

Cyclonic Scrubber

In cyclonic scrubbers, radial sprays are introduced into typical dry-type cyclones. The liquid phase assists in collection and also serves to decrease re-entrainment. Pressure drops are usually 2 to 8 in. H_2O, and water consumption is roughly the same as for the venturi scrubber.

When particle-liquid contact is obtained as the result of the carrier gas velocity itself, the scrubbers are classified as inertial scrubbers. They are of two types. One is the impaction scrubber, in which the liquid and gas phases are intimately mixed and then impacted onto a baffle plate; the second is the deflection-type scrubber, in which the gas stream impinges on liquid-film covered baffles. In the former type, impaction velocities are from 30 to 150 ft/sec, and pressure drops may be as high as 30 in. H_2O. In the latter, pressure drops are appreciably lower, ranging up to about 6 in. H_2O.

Packed scrubbers are conventional, packed tower liquid-gas contactors. Packing may be composed of Raschig rings, Berl saddles, fiberglass, etc., and gas and liquid flows are normally countercurrent. The separating mechanism is believed to be primarily impingement of the particles on the packing with the liquid medium serving merely to clean the packing surface. Excessive velocities through these units produce channeling with resultant loss of efficiency. Pressure drops range from ½ to as high as 10 in. H_2O.

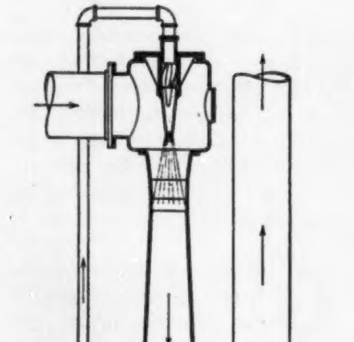


Fig. 11 — Jet scrubber.

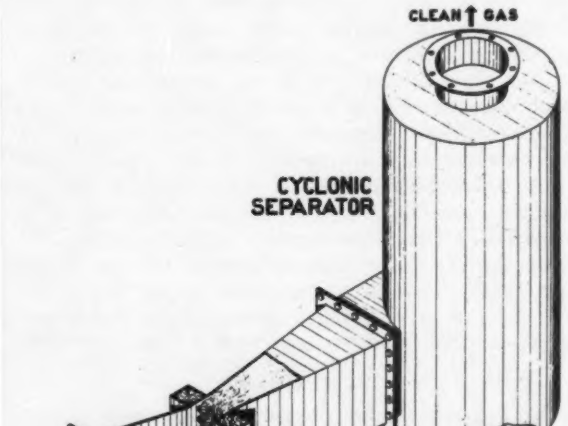


Fig. 12 — Venturi scrubber.

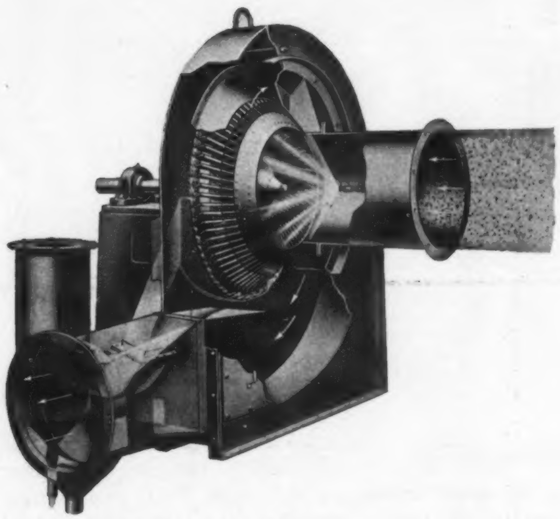


Fig. 13 — Mechanical scrubber.

Mechanical Scrubbers

In the final category are the mechanical scrubbers (Fig. 13). Here, liquid-particle contact is achieved by the simultaneous introduction of the liquid medium and the gas stream onto rotating disks, blades or perforated plates. In some cases, stationary members are alternated with the rotating elements.

Advantages associated with scrubber collectors are relatively high efficiency collection of particles in the 5-10 micron range at nominal power consumption, potentially high efficiency collection of smaller particles with adequate power consumption, moderate initial cost and applicability for high temperature service. Among the disadvantages are wet disposal of collected material which can lead to water pollution problems, high power usage for high efficiency collection of fine particles and moderate to high maintenance costs due to wet corrosion and abrasion.

CONCLUSION

Presented in table form is a summary of the general performance specifications for the various types of dust collection equipment. Included are approximate cost figures for the various types of collectors.

It is important to remember that from a technological standpoint all particulate emissions can be controlled to better than 99+ per cent efficiency through use of appropriate collection equipment. It is equally important to remember that cost of collection increases with collection efficiency, with the severity of the collection conditions and with decreases in particle-size of the material to be collected.

If required collection efficiency is based on local air pollution control legislation, the criterion for satisfactory control normally is based on either effluent loading (grains/ft^3) or upon plume opacity (Ringelmann number). If the requirement is in terms of effluent grain loading for the process concerned, then collection equipment may be selected on the basis of an overall collection efficiency by weight. However, if plume opacity is of concern, then even high weight collection efficiencies, e.g., 98+ per cent, may be unsatisfactory, since the small particles contribute little to weight but by far the most to light scatter because of their high surface-to-weight ratio.

The selection of a dust collector for a given application, therefore, requires consideration of the various possible types in terms of all the selection criteria outlined earlier, but the most important of these must inevitably be collection efficiency. In short, the collector must do the job it is supposed to do.

ACKNOWLEDGMENT

Illustrations were provided through the courtesy of the following companies: Aerodyne Development Corp., Kirk & Blum Mfg. Co., Western Precipitation Corp., American Air Filter Co., Inc., Wheelabrator Corp., Day Co., Pangborn Corp., American Foundrymen's Society, Schutte and Koerting Co. and Chemical Construction Corp.

APPROXIMATE CHARACTERISTICS OF DUST AND MIST COLLECTION EQUIPMENT

Equipment Type	Purchase Cost* (\$/cfm)	Smallest Particle Collected (microns)**	Pressure Drop (in. H_2O)	Power Used† (kw/1000 cfm)	Remarks
A. *Settling Chambers*					
1. Simple	0.1	40	0.1-0.5	0.1	Large, low pressure drop, precleaner
2. Multiple tray	0.2-0.6	10	0.1-0.5	0.1	Difficult to clean, warpage problem
B. *Inertial Separators*					
1. Baffle chamber	0.1	20	0.5-1.5	0.1-0.5	Power plants, rotary kilns, acid mists
2. Orifice impaction	0.1-0.3	2	1-3	0.2-0.6	Acid mists
3. Louver type	0.1-0.3	10	0.3-1	0.1-0.2	Fly ash, abrasion problem
4. Gas reversal	0.1	40	0.1-0.4	0.1	Precleaner
C. *Cyclones*					
1. Single	0.1-0.2	15	0.5-3	0.1-0.6	Simple, inexpensive, most widely used
2. Multiple	0.3-0.6	5	2-10	0.5-2	Abrasion & plugging problems
3. Mechanical	0.2-0.6	5	—	0.5-2	Compact
D. *Filters*					
1. Tubular	0.3-2	<0.1	2-6	0.5-1.5	High efficiency, temp. and humidity limits
2. Reverse jet	0.7-1.2	<0.1	2-6	0.7-1.5	More compact, constant flow
3. Envelope	0.3-2	<0.1	2-6	0.5-1.5	Limited capacity, constant flow possible
E. *Electrical Precipitators*					
1. One-stage	0.6-3	<0.1	0.1-0.5	0.2-0.6	High efficiency, heavy duty, expensive
2. Two-stage	0.2-0.6	<0.1	0.1-0.3	0.2-0.4	Compact, air conditioning service
F. *Scrubbers*					
1. Spray tower	0.1-0.2	10	0.1-0.5	0.1-0.2	Common, low water use
2. Jet	0.4-1	2	—	2-10	Pressure gain, high velocity liquid jet
3. Venturi	0.4-1.2	1	10-15	2-10	High velocity gas stream
4. Cyclonic	0.3-1	5	2-8	0.6-2	Modified dry collector
5. Inertial	0.4-1	2	2-15	0.8-8	Abrasion problem
6. Packed	0.3-0.6	5	0.5-10	0.6-2	Channeling problem
7. Mechanical	0.4-1.2	2	—	2-10	Abrasion problem

*Steel construction, not installed, includes necessary auxiliaries, 1960 prices.
**With ~90-95% efficiency by weight.
†Includes pressure loss, water pumping, electrical energy.

OXYGEN-GAS BURNER USE FOR SCRAP MELTDOWN IN THE SMALL ARC FURNACE

by Vernon J. Howard

ABSTRACT

The author discusses initial trials of a new process to promote rapid and uniform scrap meltdown. While the oxygen-gas burners were designed for large furnaces they have the possibility of being used as tools in the small arc, and will help the old shop keep pace with newer and larger equipment.

INTRODUCTION

In the steel casting industry, the plant layout must be flexible enough to change with faster, modern equipment and job techniques. During the past decade, the melter has met the challenge with the aid of more transformer capacity, oxygen practice for decarburization, incentive systems and other methods of decreasing melt time while maintaining quality. At the time, each of these methods seemed to be all that could be done before investing in more or larger melting units.

V. J. HOWARD is Melting Foreman, Oklahoma Steel Castings Co., Tulsa.

OXYGEN-GAS TORCH

During the past year, the oxygen-gas auxiliary torch has further decreased the melt cycle. It is interesting to note that during the war period, the same equipment taxed to the limit, was actually operating at 65 per cent of the present capacity (Fig. 1). The unit is an acid lined, 8 ft shell. The average size heat is 7800 lb. The shell is powered by a 2000 kva transformer. However, the transformer oil is externally cooled in a fin tube heat exchanger, which increases the tranformer capacity to approximately 2500 kva. The steels produced range from plain carbon to A.I.S.I. 347 stainless.

The torch was originally designed for multiple sidewall installations on the open hearth furnace.

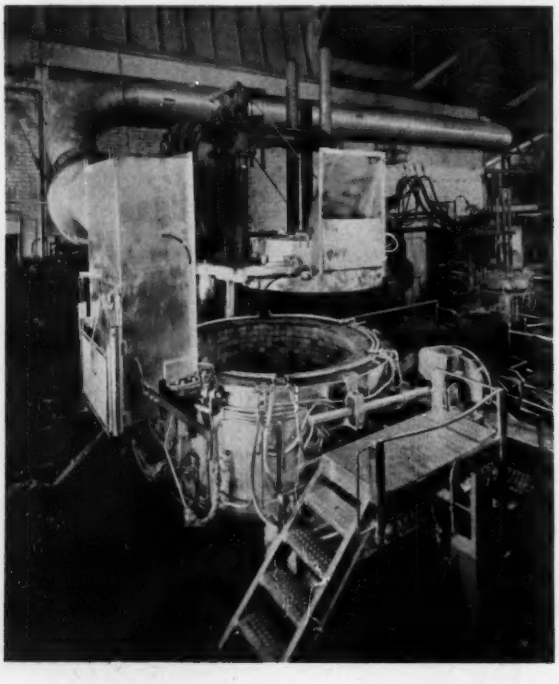
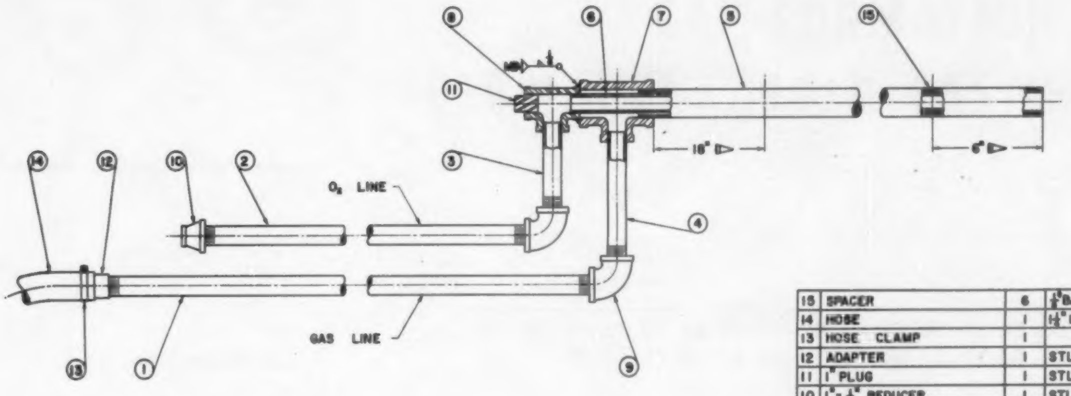


Fig. 1 — Equipment installed at the author's company. It is an acid-lined 8 ft shell.



NOTES -

ALL O_2 PIPE & FITTINGS MUST BE CLEANED WITH CARBON TET. (CCL_4).
6000 C.F.H. O_2 CONSUMPTION.
4,000 C.F.H. GAS CONSUMPTION.
▷ 3-1/2" SPACERS 120° APART WELD TO 1" PIPE.

NO.	PART NAME	REQ'D.	MATERIAL
15	SPACER	6	1/2" BAR STK. 1/16" LG.
14	HOSE	1	1 1/2" I.D. HOSE
13	HOSE CLAMP	1	
12	ADAPTER	1	STL.
11	1" PLUG	1	STL.
10	1" x 1/2" REDUCER	1	STL.
9	1" 90° ELL	2	STL.
8	1" x 1" x 1" TEE	1	STL.
7	1 1/2" x 1 1/2" x 1" REDUCING TEE	1	STL.
6	1" PIPE 4'-4" LG.	1	SST.
5	1 1/2" PIPE 4' LG.	1	BLACK PIPE
4	1" PIPE 6" LG.	1	BLACK PIPE
3	1" PIPE 4" LG.	1	BLACK PIPE
2	1" PIPE 3'-6" LG.	1	BLACK PIPE
1	1" PIPE 4'-4" LG.	1	BLACK PIPE

Torch For Furnace

Fig. 2 — Lance installation at the author's company.

When it was applied with some success on the large arc furnace, its potential on the small arc was considered at the author's company. Early attempts were made with various designs of water cooled lances that proved to be inefficient and too cumbersome for convenient use in the restricted areas usually associated with the small arc furnace. The arrangement shown in Fig. 2 was constructed at little expense and applied with much better results.

This design is in a black, one in. oxygen pipe inside a 1½-in. natural gas pipe. There is no water cooling, and the only problem experienced is occasional splatter at the tip of the lance. This is generally chipped off, or in severe cases, about one in. of the pipe is cut off the end of the pipe. The recommended flow for this lance, on an 8 ft shell is 6000 cf of oxygen and 4000 cf of natural gas/hr, a ratio of 1.5 to 1.0. The natural gas pressure at the melting unit is only 3300 cf/hr, so the oxygen pressure is lowered to 5000 cf/hr to maintain the 1.5 to 1.0 ratio.

FIRING THE TORCH

Figure 3 is a cutaway top view of the furnace, showing the lance in operating position. The torch is injected through a horizontal slot in a stationary screen shield into the furnace door. This gives the operator protection without decreasing his visibility or the maneuverability of the torch. The torch is fired as soon as the roof is swung back over the shell, and continued until all of the scrap is melted in, which is about 30 min.

The procedure adopted is to cut out the center of the charge, sloping the scrap at a 90 degree angle on each side of the electrode to prevent a scrap slide. By cutting under the electrodes a pool of metal is formed early, giving more arc stability and efficiency. A problem was created by the hood outlet over the door of the furnace. The suction at this point with the door open caused the door raising mechanism to be enveloped in flames, and the added heat caused repeated failure of pins, arms and hinges.

This, of course, caused repeated interval shut downs for replacement of parts until the entire assembly was changed to type 310 stainless which has eliminated the problem.

After several heats had produced encouraging results, it was decided that the best means of determining the economics of the use of the auxiliary burner would be to run a series of heats using both standard and auxiliary meltdown on the same day, so that uniform refractory and scheduling conditions might be obtained. This was accomplished by alter-

Fig. 3 — Cutaway view of furnace showing lance in operating position.

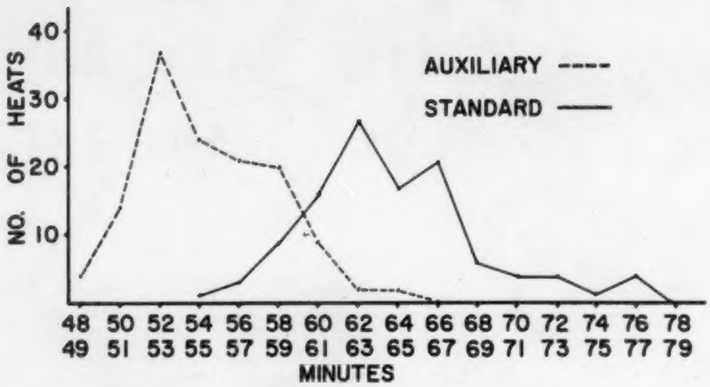


Fig. 4 — Frequency in cell graph vs. standard meltdown.

nating melting procedures for heats scheduled throughout the day. The comparison chart in the table sums up the results of the tests. There were 257 heats made, and all heats recorded were plain carbon and low alloy.

COMPARISON DATA STANDARD PRACTICE VS. AUXILIARY MELTDOWN

	Standard	Auxiliary
No. of heats	123	134
Power on to power off – avg. min.	64.92	54.86
Pounds melted per min.	111.82	128.68
KWH per ton – avg.	449.93	394.56
Iron ore per ton	25.11	6.81
Carbon drop per min. – avg.	9.49	10.10
Tapping temperature – F, avg.	3073	3088
Auxiliary O_2 per ton – est., c.f.		640
Natural gas per ton – est., c.f.		425

SAVINGS ACHIEVED

The heat time, power on to power off, shows a savings of 10 min/heat. This ties in with the increase of 17 lb melted/min. The savings on electrical power averaged 55 kwh/ton of steel produced.

Due to the oxidizing atmosphere created by the burner, the rate of carbon removal and iron ore consumption were closely observed in an effort to maintain the proper FeO in the slag. As the chart shows, the proper carbon reduction was obtained with 75 per cent less iron ore.

As the temperature comparison indicates, there was no problem in obtaining the required temperatures with the faster melt cycle. These readings were obtained with an immersion pyrometer, read from a test spoon 8 in. in diameter.

The oxygen and natural gas consumption are calculated figures, since the flow meters were used only to calibrate the regulator gages at the start of the test.

During the test period, a frequency in cell chart was maintained. All of the data obtained were used to prepare the graph shown in Fig. 4. This graph bears out the comparison chart as to the 10 min saving in the heat time. The foundry can now expect to receive most of the heats in 52 and 53 min, compared to 62 and 63 min by the standard method. Also, the auxiliary peak indicates that with the aid of the burner as a meltdown tool, some of the variables of meltdown are eliminated, thus giving less spread in total heat time.

COMPARISON TESTS

Tensile and impact comparison tests were made to check the effect on the physical quality of the steels produced during the test period. There was no indication of any decrease in quality in any heat where the burner was used. This stimulated interest in the economics of the operation. While it was known that the tangible items such as oxygen and natural gas were one dollar a ton in excess of the savings on electrical energy there were many intangible savings, such as the value of time saved, refractory costs and effect on electrode consumption, which could only be determined over a longer testing period.

For a two-month period, melting was restricted to the judicious use of the burner. Due to production schedule and distribution of molds, this proved to be practically continuous. There was a slight increase in refractory life and a decrease in electrode consumption, but not sufficient to say that the practice was a contributing factor. Although melting costs were up, the adjustment reflected in other departments of the plant showed a lower total cost per ton figure. These two months produced the lowest cost figure for any two-month period of the fiscal year. Until this figure is affected, the use of the torch will be continued and will be considered economical at the author's company.

SUMMARY

The average total power was reduced approximately 15 per cent. The tap to tap time was reduced by 15 per cent, while the production was increased by 15 to 20 lb/min. Average oxygen consumption was 600 cu ft/ton, while average natural gas consumption was 400 cu ft/ton. Electrode and refractory consumption were normal. Melting costs are up slightly, but plant costs were lower.

It is apparent that the use of the oxygen-gas burners cannot be justified on power savings alone, unless their use is restricted to avoid excessive power rate penalties. The foregoing results can be attributed to increasing production when it was required by increased molding capacity, aiding an undersized transformer and eliminating excessive overtime.

GAP FORMATION IN PERMANENT MOLD CASTINGS

by J. G. Henzel, Jr. and J. Keverian

ABSTRACT

When a metal is cast into a permanent mold, a gap gradually forms at the interface. There are several reasons why gap formation is important:

1) As it forms, the mode of heat transfer changes from that of conduction to that of radiation and, as a result, the rate at which heat can be transferred from a casting to the mold is gradually reduced, increasing casting freezing time.
2) Since the structure of a solidifying casting also depends in part upon the freezing rate, changes in the freezing rate can affect casting structure.
3) In permanent molds, the gap does not form about the entire casting instantaneously, but progresses around it generally from the top to the bottom or vice versa, affecting the location of the shrinkage within the casting.

Thus, since gap formation is an important factor in the solidification of metals in permanent molds, one must clearly understand its mechanism before an analysis of the freezing process can take place. The purpose of this investigation is to present the results of a literature survey to determine what is known to date about the mechanism of gap formation in permanent molds and, if possible, to indicate additional areas in which information is needed.

GAP FORMATION MECHANISM

Previous Theories

In 1929 Matuschka[1] made the first systematic investigation on the subject of gap formation, and suggested that a gap is formed as a result of the mold expanding due to its absorption of heat, and to the cast metal shrinking due to its loss of heat. Matuschka showed that specifically (by volume) cast steel contracts 0.4 per cent for every 180 F of superheat lost and an additional 4.0 per cent on freezing.

Paschkis[2] as well as Carpenter and Robertson[3] suggested that once the frozen skin breaks away from the mold wall, it heats up and becomes plastic and then melts or breaks through, allowing the core of molten steel to refreeze against the mold wall. The refrozen steel then contracts and breaks away again, leading to a cyclic process that Paschkis calls "breathing." Although bleeding of an ingot does occasionally occur,[4,5] Linacre[6] states that no results support the hypothesis of a cyclic process.

Mackenzie and Donald[7] point out that since the skin heats up after it breaks away from the mold it must expand, but that a gap still exists since the mold has already expanded by a greater amount. On the other hand, Glaisher and Butler[8] suggest that the inner wall of the mold may expand initially inward just after pouring because of the localized temperature rise. This would account for the high tensile stresses Herne[9] found on the outside of the mold about 6 min after pouring.

Mackenzie and Donald[7] also showed how mold temperatures varied from the bottom of an ingot to its top. Their data indicated that the bottom sides of the mold reached maximum temperature before the top and, as a result, that gap formation started there.[10] Although there may have been a delaying effect due to the high ferrostatic pressure, it apparently was not great enough to prevent the gap from initiating at the bottom.

However, Livshits[11] found out that for ingots top poured at a rapid rate, the gap may even start to form at the top and progress downward. He attributed this rather startling effect to the rapid loss of heat out the top of the ingot by radiation to the atmosphere, and by conduction up through the cold mold walls of the ingot. Therefore, there are various theories and data on gap formation in the literature which help to lend an understanding.

Experimental Data

There are also, however, other data in the literature which can be analyzed and interpreted in order to gain an even better understanding of the mechanism of gap formation. These include:

1) Measurement of casting and mold interface temperatures.
2) Calculating the change in the rate of heat transfer by means of the measurement of temperature gradients within the mold.
3) Analysis of gap formation as a thermal resistance.
4) Calculating the width and time of gap formation.
5) Measuring the time required for gap formation and other miscellaneous and indirect approaches.

Measurement of Interface Temperatures. One can estimate when a gap starts to form by measuring the interface temperatures and noting when a sharp change in these temperatures occurs. Atterton,[12] in collaboration with Houseman,[13] has developed a technique of inserting bare thermocouple wires through a mold wall in such a way that on entry of molten steel into the casting, contact between the two

J. G. HENZEL is Applied Rsch. Engr., and J. KEVERIAN is Mgr., Applied Rsch. & Dev., Foundry Dept., General Electric Co., Schenectady, N.Y.

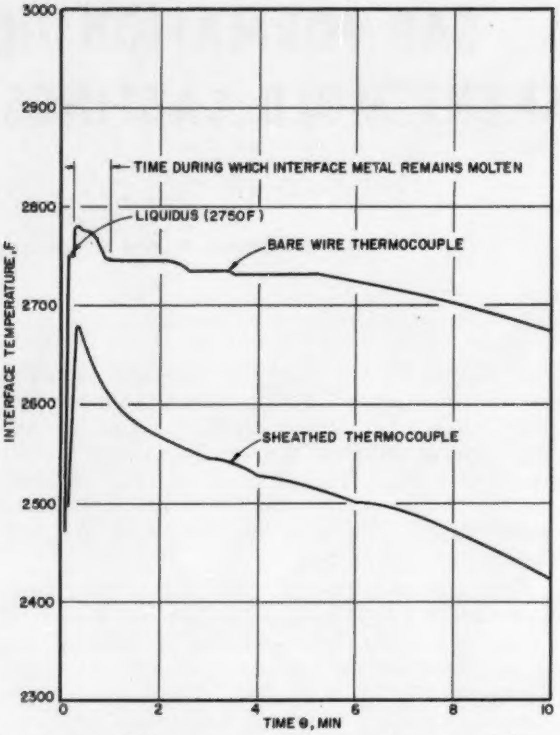


Fig. 1 — Mold-metal interface temperatures for steel cast in sand. Data replotted from reference 13. Pouring temperature 2875 F. Bare wires protrude approximately ¼-in. into mold cavity.

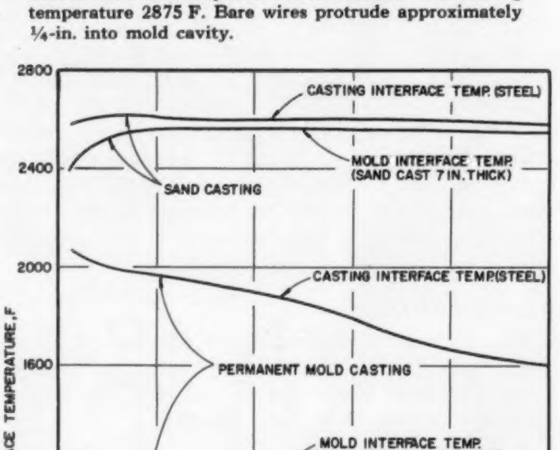


Fig. 2 — Interface temperatures in sand and permanent molds for cast iron and steel. Data replotted from reference 14. Steel pouring temperature 2800 F. Mold temperature 80 F. Casting geometry 7 in. square ingot 20 in. high. Data obtained at half height position.

wires occurs, and interface temperature readings are then obtained. Since this type of thermocouple has only a slight heat capacity, its response is rapid, and, as a result, accurate temperatures directly at the interface can be obtained.

Houseman's results[13] on a 280-lb steel casting poured at 2875 F into sand are replotted as Fig. 1. For comparative purposes, his results obtained with a sheathed thermocouple for the same sand casting are also shown. The bare wire thermocouple shows a short arrest initially at the liquidus temperature (2750 F) corresponding to the remelting of the initial chilled layer of metal. Because of the heat in the mass of the oncoming liquid steel, the chilled layer melts and the interface temperature then rises to 2780 F.

Molten Metal at Interface. The metal at the interface then stayed molten for 50 sec, after which it remained refrozen. The sheathed thermocouple, however, due to its thermal lag, failed to show that such phenomena occurred. Thus, the use of sheathed thermocouples may result in major inaccuracies when recording rapidly changing interface temperatures. Atterton's experiments to date have been restricted to sand castings, but a bare wire couple such as his could be used to accurately record interface temperatures in permanent molds, and in this way be used to detect gap formation.

Bishop and Pellini[14] also measured interface temperatures with thermocouples of the sheathed type having but a small mass. These data were obtained with liquid steel poured into both sand and cast iron (permanent) molds. Some of these data are reproduced in Fig. 2. The upper two curves are the interface temperatures that were recorded when a steel ingot 7 in. square and 20 in. high was cast into a green sand mold 7 in. thick. The lower two curves are the interface temperatures that were recorded when the same size ingot was cast into a cast iron "permanent" mold with a mold wall 1½-in. thick. These data were obtained at the mid-height of the ingot.

Although the ladle pouring temperature was 2800 F, the thermocouples at the ingot mid-height indicated that enough heat was absorbed by the mold by the time the metal reached the thermocouples to reduce its temperature to about 2600 F.

Note in Fig. 2 that for the sand casting, both interface temperatures were nearly that of the pouring temperature. This indicates that the two surfaces were probably in close contact (no gap formation), and that the sand mold was a rather poor conductor of heat.

Permanent Mold Interface Temperatures. On the other hand, for the permanent mold casting, the interface temperatures are radically different from each other and both much lower than the pouring temperature. The large difference in their temperatures is probably due to the early formation of gap which, from the sharp decrease in the rate at which these two interface temperatures initially approached one another, appears to have started to form about one min, or perhaps even sooner, after pouring commenced.

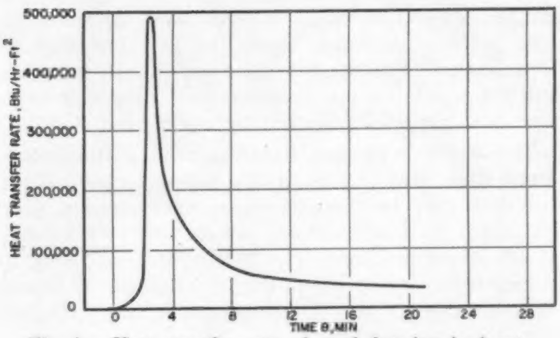


Fig. 3 — Heat transfer rate of steel freezing in ingot mold.[7]

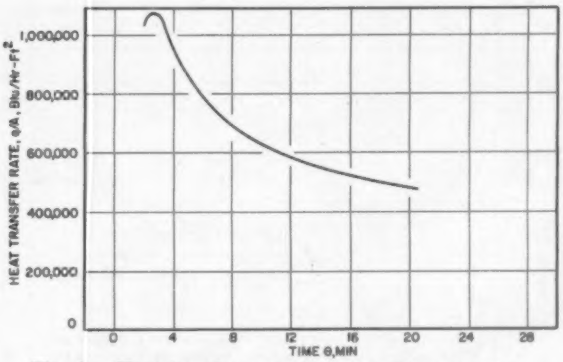


Fig. 4 — Heat transfer rate of steel freezing in water-cooled mold.[18]

Had the two surfaces remained in contact, a common interface temperature of about 1540 F would have been established (method of Horvay and Henzel[15]). Both interface temperatures are much lower than the temperature of the steel, since cast iron has a much greater ability to transmit heat than does sand.

Bishop, Brandt, and Pellini[16] have confirmed that these inflections are the result of gap formation by inclining a mold at 45 degrees. Under these circumstances, the interface temperature on the upper side of the mold showed an inflection, whereas that on the lower side did not. This was the expected result, since the lower side of the mold must have remained in good contact with the ingot.

Thus, it appears that gap formation in permanent molds induces a sharp change in both the casting and mold interface temperatures.

Calculating the Change in the Rate of Heat Transfer. Mackenzie's and Donald's data,[7] showing the rate of heat transfer in an ingot mold when steel freezes, are replotted as Fig. 3 of this report. From these data, it can be seen that the heat transfer rate is initially zero, quickly reaches a sharp maximum (about 2½-min after pouring) and then rapidly falls off with time. The sharpness of this maximum is increased, according to Bailey,[17] as the measuring thermocouple approaches the mold surface.

Data of Crane and Linacre,[18] showing the rate of heat transfer when steel freezes in a water-cooled mold, are replotted as Fig. 4 of this report. Although the heat transfer rate has initially increased as a result of water cooling, the shape of the curve is still similar to that of Fig. 3. Almost instantly after the liquid metal touches the mold wall, the rate of heat transfer reaches a maximum and then rapidly falls off with time.

Linacre[6] associates the peaks in the data on Figs. 3 and 4 with the formation of a gap and states that "It is usually assumed that the maximum heat transfer rate occurs just before the gap forms between an ingot and the mold." All will subsequently be shown, both theoretical considerations and heat transfer analysis of Bishop's and Pellini's experimental data confirm his assumption.

Theoretical Considerations Which Tend to Confirm Linacre's Assumption. The well-known equation for conduction heat transfer states that:

$$q/A = K \frac{\Delta^T}{\Delta^x} \qquad (1)$$

Where

q/A = Heat transfer rate per unit area into the mold.

K = Thermal conductivity of the mold.

Δ^x = Distance between the casting mold interface and a thermocouple used to record another temperature within the mold.

Δ^T = Difference between the temperature at the casting mold interface and that within the mold.

(All symbols used in this report are defined in the Appendix.)

At the instant the cast metal contacts the mold, Δ^T is at its maximum and thus the heat transfer rate (q/A) is also at its maximum. Since Δ^T decreases continuously after pouring, however, the heat transfer rate must also decrease continuously. Thus, the above equation tells us that at the instant a cast metal contacts a mold, the heat transfer rate is at a maximum and that it decreases continuously thereafter.

Heat Transfer Analysis of Gap Formation Confirming Linacre's Assumption. As outlined in the Appendix, one may estimate the heat transfer rates into permanent molds both with and without gap formation. Fortunately, Bishop and Pellini[14] have obtained the necessary temperature distributions within cast iron molds of 1½, 2½ and 4⅛-in. thicknesses. As a result, the heat transfer rates into these molds both with and without gap formation were calculated. The results are shown in Fig. 5. The dotted lines are the rates which would have been obtained had no gap formed. The solid lines are those rates actually obtained as the gap formed.

It was noted that the initial heat transfer rates are quite high, but that they rapidly drop off to lower values regardless of mold wall thicknesses. Note also that as mold wall thickness increases, the heat transfer rate increases but that the effect of gap formation is to reduce the overall rate of heat transfer into the mold, reducing the chilling effectiveness of the mold material. One can also see that during the time

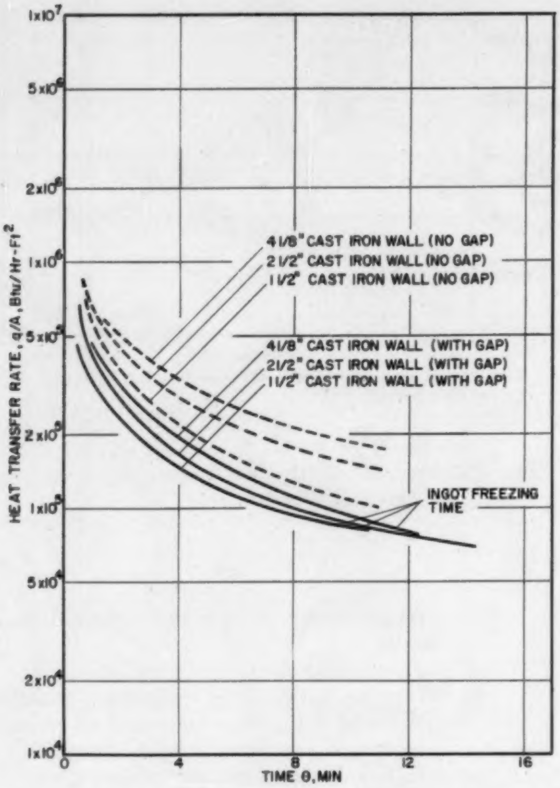


Fig. 5 — Heat transfer rates into permanent molds. Pouring temperature 2795 ± 5 F. Ingot 7 in. square, 20 in. high. Data calculated from references 14 and 15.

interval shown, the heat transfer rates with gap formation are about one-half those without gap formation.

In order to determine what part of the total heat transferred across the gap during solidification was by radiation alone, the ratio of the radiation heat flow to the total heat flow across the interface has been plotted in Fig. 6.

Note that, in general, the portion of the heat transferred by radiation increases with time (gap width increasing) and decreases as mold wall thickness increases. Note also that again the gap appeared to form in less than one min, but that for these molds full gap width was not obtained, indicating that some heat was always transferred by conduction.

The Analysis of Gap Formation As a Resistance Formation. The formation of a gap at a casting-mold interface may be thought of as the formation of a resistance to heat transfer which increases as gap width increases. Thus, gap formation might be simulated in an analog computer, for example, by means of a variable resistor. The variation in gap resistance can be determined by:

$$q = \frac{\Delta^T}{\frac{(\Delta^x)}{(KA)}} \tag{2}$$

This equation for heat flow is analogous to Ohms laws for current flow, $I = \frac{E}{R} \cdot \frac{\Delta^x}{KA}$ is thus the gap thermal resistance corresponding to heat flow as the electrical resistance (R) does to current flow.

The heat transfer rate (q/A) has been determined in Fig. 5. Δ^T, the interface temperature difference has been measured by Bishop and Pellini. The remaining unknown, gap resistance, is thus determined. Its value has been calculated for cast iron mold wall thicknesses of 1½, 2½ and 4⅛-in., plotted as Fig. 7.

It can be seen that the trends of the curves are quite similar to those of Fig. 6. As solidification occurs the thermal resistance increases (increasing gap width), and that as mold wall thickness increases thermal resistance decreases. Resistance variations such as these could be duplicated in an analog computer by means of variable resistors, thereby simulating gap formation in permanent molds.

Calculating the Width and Time of Gap Formation. Linacre[6] also outlined in detail a calculation of the movement of the ingot and mold surfaces after pouring. His data indicated that separation of a

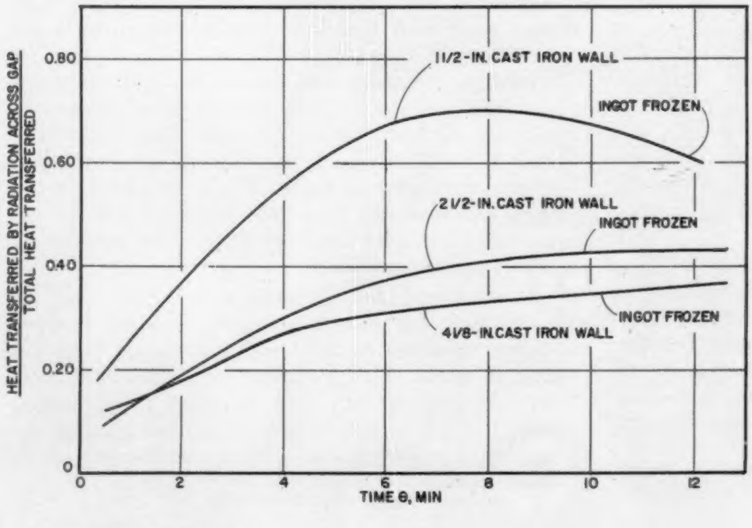


Fig. 6 — Portion of the total heat transferred by radiation across the mold-ingot interface. Pouring temperature 2795 ± 5 F. Interface emissivity 1.0. Data calculated from reference 10. Initial mold temperature 70 F.

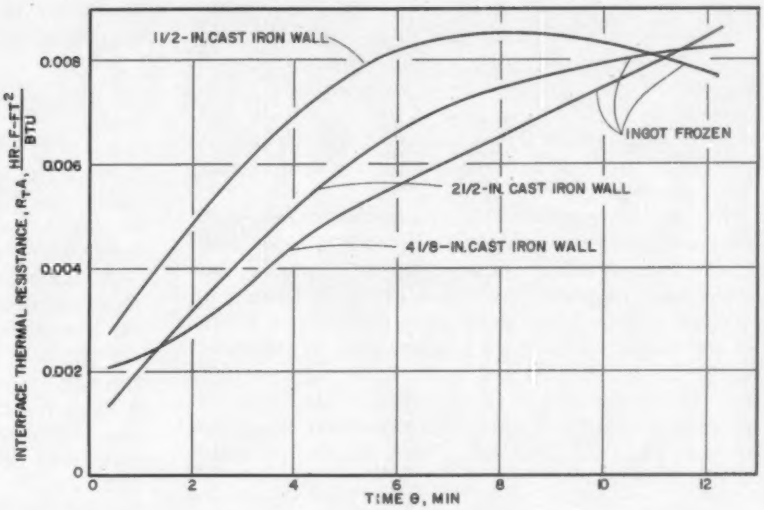


Fig. 7 — Thermal resistance of an ingot-mold interface. Pouring temperature 2795 ± 5 F. Data calculated from reference 14. Initial mold temperature 70 F. Ingot 7 in. square, 20 in. high.

1/3-ton ingot from its mold wall took place about 2 min after pouring, and that the gap width rapidly increased to 0.1 cm. He showed that for the next 18 min the gap width remained almost constant, since both the mold and ingot surfaces were expanding at about the same rate.

Buckland[20] also calculated the time of gap formation of a 150 ton ingot. Her calculations, based on those of a 3 ton ingot, indicated that gap formation initiated at the bottom of the sides about 20 min after pouring, and at the top about one hr after pouring was complete. She indicated that heat conducted through the mold wall above the advancing level of the liquid steel during pouring, pre-expands the mold and accounts for the delay with height of the onset of gap formation.

Lightfoot[21] also calculated the time of gap formation, and indicated that both preheating the mold and increasing ingot size delay the formation of a gap.

Measuring the Time Required for Gap Formation. Evidence on the elapsed time between pouring and gap formation comes from several experimenters. Mykura[22] actually measured the time it took a gap to form by means of small insulated probes whose ends were flush with the inner surface of a 1 in. diameter water cooled mold. Once steel was poured, contact was established for the probes, lighting bulbs in series in the circuit. Once the gap formed, the lights went out and the time that they were lit furnished a direct measurement of the time it took to form the gap. Four such probes were mounted in the mold at the same height, and the lengths of time the lights were lit during each of three experiments are repeated in the table.

SEPARATION TIMES IN MYKURA EXPERIMENTS[22]

Experiments	Separation Times of 4 Probes (Sec)			
1	11	14	—	—
2	6	6	12	—
3	3	15	—	—

As Linacre[6] has commented, there is wide scatter in these data and, surprisingly, 5 out of 12 measurements indicate that the steel never touched the probes. The average time of separation of the above readings is 5.6 sec.

Matuschka[1] used a similar apparatus with electric bells to indicate contact between the ingot and the mold wall. He used two probes; one on each of two adjacent walls of a 1/3-ton ingot mold and 10 in. from the top surface. His data for a top-poured ingot, although somewhat erratic, indicated that a gap formed between a 10 in. diameter medium carbon steel ingot and a mold wall 3 1/8-in. thick, only 1 min 25 sec after pouring.

Livshits[11] study was aimed at determining the influence of pouring practice upon the time at which a steel ingot detaches from the mold. The ingots were of the big end down type, 15.7 in. inside diameter, and 72.8 in. in length. Three pairs of holes were drilled at levels 5.1, 31.1 and 49.7 in. from the ingot bottom.

Carbon electrodes 3.54 in. apart were arranged flush with the inside wall of the mold and connected to three 12-volt light bulbs. Livshits found that in bottom pouring the gap formed first in the lower portion of the mold 2 - 3 min after pouring started, 10 - 11 1/2-min at a height 31 in. above the bottom and 12 - 13 min at the ingot top. Mold filling time averaged 6 min 10 sec.

In top pouring, on the other hand, he found that the gap formed first in the top portion of the mold after 9 min, in the middle after 13 min and in the lower part after 14 1/2-min. Pouring time was 35 sec in this case.

He attributes the differences in gap formation both to variation in the flow of the molten metal in the mold during solidification, as well as to mold filling time variations. For the top-poured, rapidly filled mold, he believed that more rapid loss of heat out the top of the ingot than out the bottom accounts for the unusual effect of the gap forming first at the top.

Various Other Miscellaneous and Indirect Approaches. Spretnak[23] observed that it was possible to see a gap by eye between the top of an ingot and

its mold about 2 min after pouring. Desars[24] lifted a new $3\frac{1}{2}$-ton big end down mold 5 min after pouring, and found that the ingot lifted with the mold and dropped out only after a further 10 min of cooling. When the ingot and mold were initially lifted, it could be seen that the base of the ingot walls had already separated, so it was concluded that separation proceeded upwards and was complete about 15 min after pouring.

In a second experiment, Desars cast the molten steel into a big end down mold fitted with a loose plug in the base on which the ingot rested. The plug and mold were supported by separate weight measuring devices, so that it was possible to find what fraction of the weight of the ingot was sustained by the mold walls. He found that the mold walls supported 34 per cent of the weight of the ingot at the finish of pouring, and that thereafter the percentage decreased to zero. The equivalent figure for a big end up mold is 50 per cent.

CONTROL OF GAP FORMATION

Walker[25] indicates that temperature gradients within a casting at the freezing metal interface are of considerable importance in determining the structure of a solidifying casting. Since the formation of a gap affects these gradients, control of the gap formation might allow one to control casting structure. From this literature search, there appear to be several ways in which to influence and perhaps thereby control gap formation.

One way is to water cool the mold. Although not necessarily desirable, this shortens the time before separation begins. A second method of varying the initial time of gap formation, according to the calculations of Lightfoot,[21] is to preheat the mold. This has the effect of delaying the time of gap formation. One may conclude from Buckland's report[20] that since heat conducted up the sides of a mold during pouring pre-expands the mold walls, the onset of gap formation should be even further delayed by slow pouring.

The duration of the transition period to full gap formation can be increased by increasing the surface roughness of either the cast metal or the mold interface, or both. Surface roughness of the casting may be controlled by the choice of the deoxidant, since the use of aluminum for killing steel leads to a much rougher surface than, say, ferromanganese.[26] Another factor is the method of pouring, as asymmetry and turbulence of the in-flowing stream will obviously lead to ingot surface roughness.

It may also be possible to control the time and formation of the gap by controlling the other variables which affect the heat transfer rate, such as mold wall thickness, liquid metal superheat and the coefficients of expansion, conductivity, density and specific heats of both the cast metal and the mold.

An idea[5] which has been used in industry, and which appears to be a way of effectively preventing separation, is to fill the air gap with liquid metal. Molten lead is poured into the mold at the same time the steel is tapped in, thus preserving metallic continuity between ingot and mold, and so maintaining a rapid and deep chill of the ingot surface.

CONCLUSIONS OF THE MECHANISM OF GAP FORMATION

From the theories and experimental data outlined above, the following conclusions on the mechanism of gap formation in permanent molds have been reached:

At the instant of contact between a cast metal and its mold, the heat is transferred by conduction at a rapid rate. Soon thereafter, a gap starts to form by the gradual contraction of the frozen metal away from an expanding mold wall. As gap formation takes place a transition period of partial contact between the casting and the mold occurs, during which the heat is transferred by both conduction and by radiation. Finally, as full gap width is attained the casting and mold surfaces no longer touch, and thereafter the heat is transferred by radiation.

The time and magnitude of gap formation appears to depend upon the many variables which affect the rate at which heat is transferred from a casting to a mold. These include, among others, casting size, mold wall thickness, mold wall roughness, mold wall temperature, liquid metal superheat, method or rate of pouring and the coefficients of expansion, conductivity, density and specific heat of both the cast metal and the mold. Separation times from about 3 sec up to as long as 20 min after pouring appear in the literature.

The location of the initial gap appears to depend again upon the many variables which affect the rate at which heat is transferred from the casting to the mold. In ingots, for example, one experimenter found that separation could be initiated at either the top or the bottom, depending upon the method of pouring which directly affected the local rate at which heat was transferred. The gap appears to initiate where the highest rate of heat transfer at the casting mold interface was obtained.

The heat transfer rate is at its maximum at the instant the poured metal touches the mold and decreases continuously thereafter.

The effect of gap formation is to reduce the rate at which heat can be transferred from a casting to the mold and, as a result, increase casting solidification time. In one case in this investigation, gap formation appeared to reduce the heat transfer rate by about one-half.

Gap formation in permanent molds induces a sharp change in both the casting and mold interface temperatures.

REFERENCES

1. Matuschka, B., *Archiv f. Eisenhuttenwesen, 2,* p. 405 (Jan. 1929).
2. Paschkis, V., *A.S.M. Transactions, 38,* p. 117 (1947).
3. Carpenter and Robertson, *"Metals" O.U.P., 1,* p. 631 (1939).
4. Savage, J., *B.I.S.R.A. Report,* P/C 27 (1949).
5. Glaisher, W., *Private Communication* (1950).
6. Linacre, E. T., *B.I.S.R.A. Report,* Pe/A/2651 (Aug. 1951).

7. Mackenzie and Donald, *J.I.S.I.*, p. 19 (Sept. 1950).
8. Glaisher, W. and Butler, M., *B.I.S.R.A. Report* SM/BA/162/49 (1949).
9. Herne, H., *B.I.S.R.A. Report* P/C 44 (1949).
10. Barber, E., *British Steelmaker*, pp. 14, 76, 123, 166 (Jan.-April 1945).
11. Livshits, A., *Teoriya I Prakika Metallurgii*, vol. 12, no. 11-12 (1940).
12. Atterton, D. V., *Foundry*, p. 78 (Jan. 1959).
13. Atterton, D. V. and Houseman, D. H., *Nature, vol. 171*, p. 980 (1953).
14. Bishop, H. F. and Pellini, W. S., *Foundry* (Feb. 1952).
15. Horvay, G. and Henzel, J. G., *G.E. Report No. 57-RL-1844* (Dec. 1957).
16. Bishop, H. F., Brandt, F. A. and Pellini, W. S., AFS TRANSACTIONS, *vol. 59* (1951).
17. Bailey, G., *J. Inst. Metals, 2*, p. 203 (1932).
18. Crane, J. and Linacre, E., *B.I.S.R.A. Report* SM/B/96/48 (1948).
19. Austin, J. B., *"The Flow of Heat in Metals,"* (1942).
20. Buckland, F. F., *Private Communication* (Jan. 17, 1957).
21. Lightfoot, N. M. H., *Iron & Steel Inst. Special Report No. 4* (1933).
22. Mykura, H., *B.I.S.R.A. Report* SM/B/96/48 (1948).
23. Spretnak, J., *Open Hearth Proceedings A.I.M.M.E.*, p. 187 (1947).
24. Desars: *Rev. de Metall*, June, p. 137 (1946).
25. Walker, J. L., *G. E. Report No. 58-RL-2026*, (1958).
26. Pritchard, W., *Private Communication* (1951)..

APPENDIX

Symbols

q — heat transfer rate, Btu/hr.

A — cross-sectional area through which the heat passes, ft².

K — thermal conductivity, $\frac{\text{Btu ft}}{\text{hr ft}^2\ \text{F}}$.

Δ^T — temperature difference, F.

Δ^x — the distance over which the temperature difference applies, ft.

I — current flow, amps.

E — voltage, volts.

R — electrical resistance, Ohms.

R_t — thermal resistance, $\frac{\text{hr} - \text{F}}{\text{Btu}}$.

q_1 — rate heat is transferred into a mold surface, Btu/hr.

q_a — heat accumulated or stored by the mold at any instant, Btu/hr.

q_o — the rate at which heat leaves the mold outer surface, Btu/hr.

$q_{radiation}$ — the rate heat is lost out a surface by radiation, Btu/hr.

$q_{convection}$ — the rate heat is lost by convection, Btu/hr.

h — the heat transfer coefficient, $\frac{\text{Btu}}{\text{hr ft}^2\ \text{F}}$.

W — weight, lb.

C_p — specific heat, $\frac{\text{Btu}}{\text{lb F}}$.

dT — temperature difference, F.

$d\Theta$ — time interval, hr.

e — surface emissivity, dimensionless.

T_o — ambient temperature, F.

T_s — surface temperature, F.

T_1 — initial mold temperature, F.

T_{av} — average mold temperature, F.

ρ — density, lb/ft³.

L — mold thickness, ft.

V — mold volume, ft³.

Heat Transfer Problem

The problem is to determine the heat transfer rate into a permanent mold of given thickness both with and without gap formation.

The general heat balance equation that applies is:
Rate at which heat enters a mold wall, q_1 —
Rate at which heat leaves a mold wall, q_o =
Rate at which heat is accumulated in the wall, q_a
or

$$q_1 = q_a + q_o$$

where

$$q_a = \left(WC_p \frac{dT}{d\Theta}\right) \text{mold}$$

and

$$q_o = q_{radiation} + q_{convection}$$

where

$$q_{radiation} = 1723\, eA \left[\left(\frac{T_s}{1000}\right)^4 - \left(\frac{T_o}{1000}\right)^4\right]$$

and

$$q_{convection} = h\, A\, (T_s - T_o)$$

now

$$h = 0.7 + \left(\frac{T_s - T_o}{375}\right),$$

the film coefficient, $\frac{\text{Btu}}{\text{hr ft}^2\ \text{F}}$, for heat transfer from a vertical wall to air stirred only by natural convection.[19]

and

$$dT = (T_{av} - T_1)_{mold}$$
$$d\Theta = \Theta\,(\text{at time}) - \Theta\,(\text{time} - o) = \Theta_{time}$$

thus,

$$q_1 = \left[WC_p \frac{(T_{av} - T_1)}{\Theta}\right]_{mold} + 1723\, eA \left[\left(\frac{T_s}{1000}\right)^4 - \left(\frac{T_o}{1000}\right)^4\right] + \left(0.7 + \frac{T_s - T_o}{375}\right)(A)\,(T_s - T_o)$$

since

$$W = \rho V = \rho AL$$

then

$$q/A = \rho L\, C_p \frac{(T_{av} - T_1)}{\Theta} + 1723\, e \left[\left(\frac{T_s}{1000}\right)^4 - \left(\frac{T_o}{1000}\right)^4\right] + \left(0.7 + \frac{T_s - T_o}{375}\right)(T_s - T_o)$$

For the case of determining q/A with gap formation, one merely needs to determine the temperature gradients within the mold so that T_{av}, the average mold temperature, and T_s, the mold surface temperature, are known.

For the case of determining q/A without gap formation, one needs to know how T_{av} and T_s vary. By the method of reference 15, a mold-metal interface temperature of 1540 F was estimated for steel at 2800 F poured into a cast iron mold at 70 F. Knowing an interface temperature, the rate at which the mold wall heats, (T_{av} and T_s), was determined by means of the tables in reference 19.

CAST IRON HEAT TREATMENT

by P. H. Dirom, Jr.

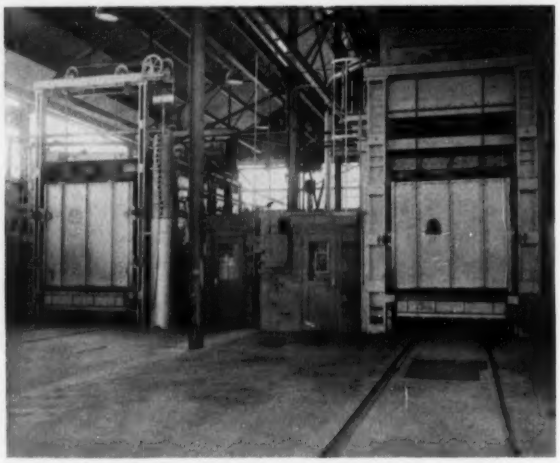


Fig. 1 — The two furnaces at the author's company with central control room between them.

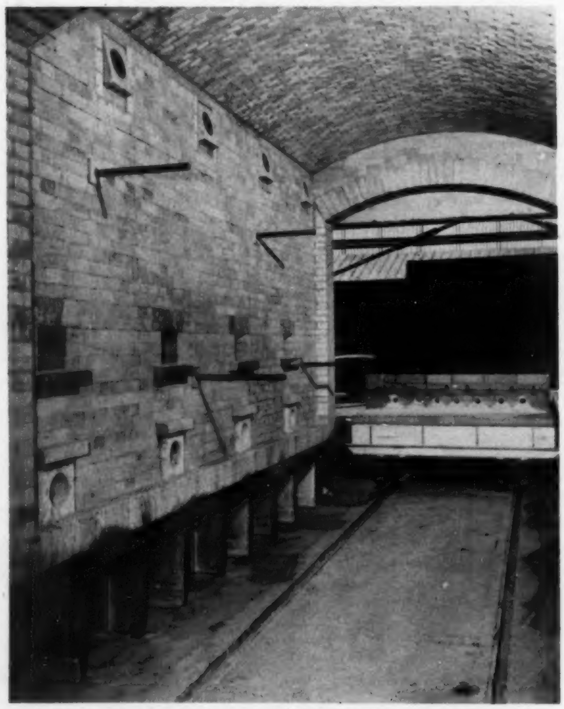


Fig. 2 — Interior of one of the furnaces.

ABSTRACT

The author deals with the various types of heat treatments which are in use at his company. Stress relieving, higher temperature stress relieving, low temperature annealing, high temperature annealing, normalizing and quenching in oil and tempering are covered. The discussion covers both gray and ductile iron.

INTRODUCTION

Heat treating is defined as an operation or combination of operations that involve the heating and cooling of a solid metal or alloy, for the purpose of obtaining certain desirable conditions or properties. In this paper the author will deal with six specific types of heat treatments:

1) Stress relieving (1050 F).
2) High temperatures stress relieving (1150-1200 F).
3) Low temperature annealing (1250-1450 F).
4) High temperature annealing (1650 F).
5) Normalizing (air cooling from 1650-1450 F).
6) Quenching in oil and tempering.

Before going into detail on these heat treatments the author would like to show some of the equipment used at his company. The metal building houses the furnaces seen in Fig. 1, the two large furnaces with the central control room between them. The furnace on the left is a large car bottom direct fired annealing furnace with an effective loading area of 186 x 72 x approximately 58 in. high.

The furnace has two cars so that when a load is pulled at the end of a heat, another loaded car can be moved into the furnace. The cars have cast iron grates on the top of brick supporting piers. The interior of this furnace is shown in Fig. 2. This furnace has 16 dual fuel burners. Natural gas is used about 80 per cent of the time, and no. 2 fuel oil the remainder. The burners are staggered on each side of the furnace and located above and below the castings to avoid impinging flame directly on the castings.

Furnace Atmosphere Temperature Measurement

The rods that protrude into the furnace contain thermocouples that measure the atmosphere temperature inside the furnace. The furnace is divided into

P. H. DIROM, JR., is Plant Met., Lynchburg Foundry Co., Lynchburg, Va.

four zones with atmosphere thermocouples in each zone to control the heating and cooling of the castings. The four square openings shown are exhaust ports equipped with dampers that can be opened and closed to control the heating and cooling rate of the castings. This furnace may be used for stress relieving, higher temperature stress relieving, low temperature annealing and high temperature annealing.

The furnace on the right is also a car bottom furnace of the same size and capacity, but here the similarity ends. The car has cast iron grates on top of heat resistant cast iron supporting beams. This furnace is a recirculating furnace and has a combustion zone on top with three dual fuel burners. Two fans with heat resistant blades blow the hot gases from the combustion zone down through the metal ducts at the side of the furnace in Fig. 3.

The hot gases go out under the grates and up through the castings into the duct in the top center where these gases are mixed with hot gases from the combustion zone and recirculated again. There is an atmosphere control thermocouple on the furnace also.

This furnace may be used for stress relieving, higher temperature stress relieving and low temperature annealing. Both furnaces have thermocouples that are attached to the castings to give actual casting temperature.

In a small bay on one side of the furnace building is the heat treating furnace. This furnace is a pit type furnace with one dual fuel burner. Figure 4 shows the operator removing a load of castings from the furnace. Behind the operator is the oil quenching tank of 2000 gallons capacity with a recirculating pump of 1200 gallons/min capacity. The furnace has a capacity of 2000 lb including the basket. The average basket weight is approximately 500 lb.

Fig. 4 — Removing a load of castings from the furnace.

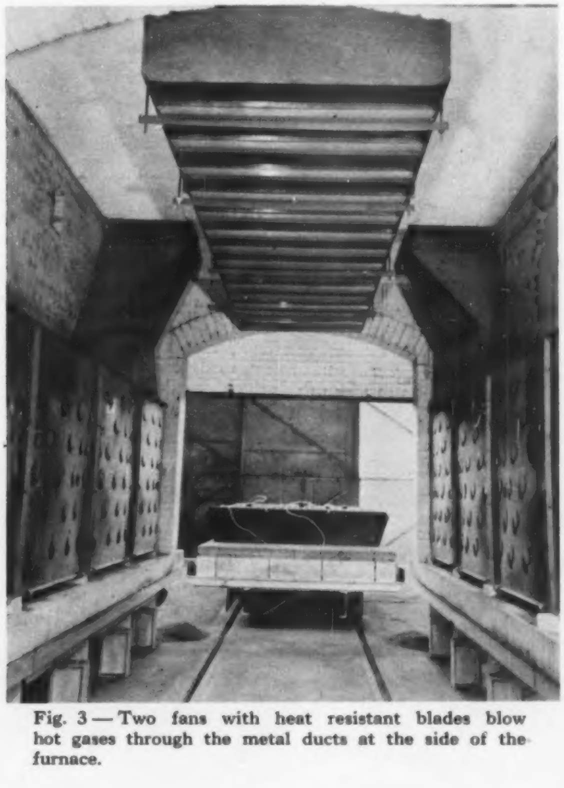


Fig. 3 — Two fans with heat resistant blades blow hot gases through the metal ducts at the side of the furnace.

This furnace is used for experimental work, for oil quenching from 1650 F and to establish cycles to be used in the big furnaces.

This furnace has a program control consisting of a plastic cam that controls the heating and cooling of the furnace. Figure 5 shows the operator installing a cam. This furnace, like the others, has a thermocouples attached to castings in the furnace. Any of the six types of heat treatment may be performed in this furnace.

GRAY AND DUCTILE IRON PRACTICE

Before we discuss specific types of heat treatment the author would like to tell you briefly about the company's gray iron and ductile iron practices. Gray iron is melted in an acid cupola, and after an inoculation with ferrosilicon the iron analyses in the range of 3.25 to 3.45 T.C., 2.00 to 2.30 Si, 0.70 to 0.90 Mn, 0.15 max. phosphorus and 0.12 max. sulfur. The tensile strength of this iron in a 1.2 in. diameter test bar is in the range of 30-33,000 psi with 180-230 Bhn.

By using alloys, the company increase the tensile strength of this iron to 35 and 40,000 psi in a 1.2

Fig. 5 — A plastic cam controls the heating and cooling of the furnace. Here it is being installed.

in. diameter test bar. The microstructure of the class 40 iron at 100× etched with 2 per cent nital is shown in Fig. 6. The structure is type A graphite in a matrix of pearlite. Ductile iron is melted in a hot-blast acid cupola with protruding tuyeres and then the sulfur is reduced from 0.08 to 0.02 per cent max. by calcium carbide injection.

After the addition of magnesium nodularizing alloys to change the graphite to nodules, and inoculants to minimize the formation of carbides the analysis of the ductile iron is generally in the range of 3.45 to 3.65 per cent T.C., 2.30 to 2.50 per cent silicon, 0.25 to 0.35 per cent manganese and 0.08 per cent max. phosphorus. Figure 7 shows a typical microstructure of the as-cast ductile iron at 100× etched with 2 per cent nital. The structure shows nodules of graphite surrounded by ferrite in a matrix of pearlite.

About 80 per cent of the ductile iron castings are shipped either as-cast or stress relieved.

HEAT TREATMENTS

Stress Relief

In each of the cycles the temperatures given are casting temperatures and not oven temperatures. The most widely used type of heat treatment is stress relief. A load of compressor cases after stress relief is shown in Fig. 8. Notice the thermocouples attached to the castings.

The cycle used is:

1) Heat to 1050 F at a rate not to exceed a minimum of 3 hr.

Fig. 6 — Class 40 iron. 2 per cent nital etch. 100 ×.

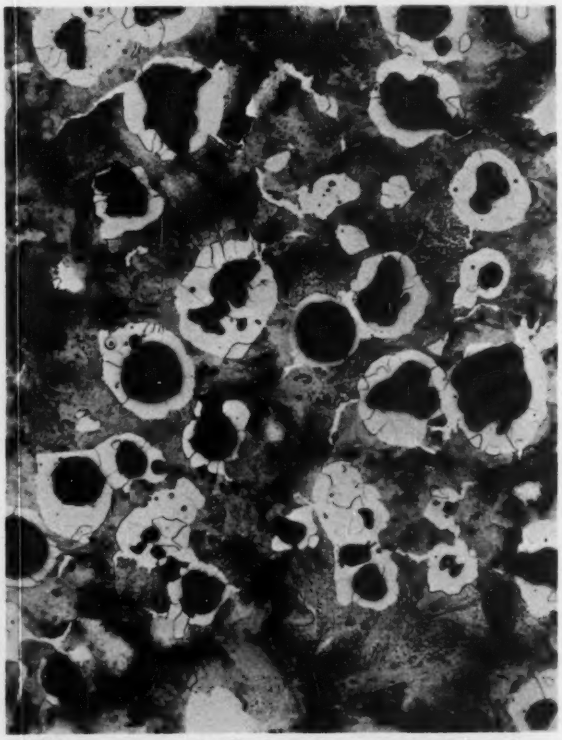


Fig. 7 — As-cast ductile iron. 2 per cent nital etch. 100 ×.

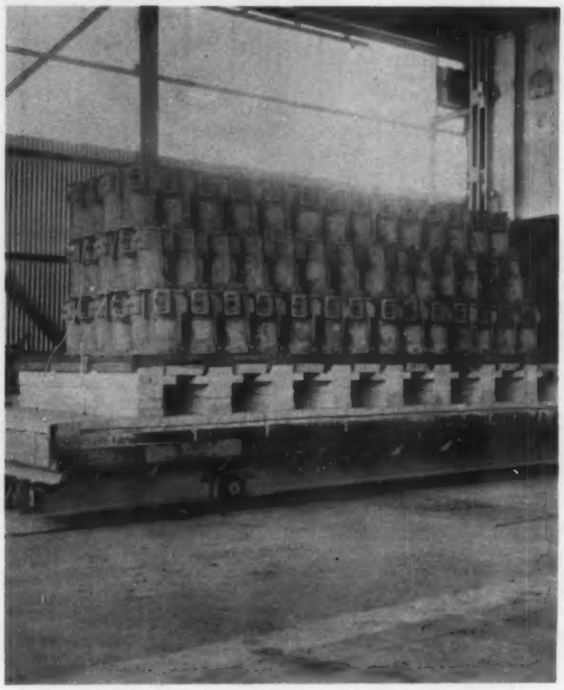


Fig. 8— A load of compressor cases after stress relief.

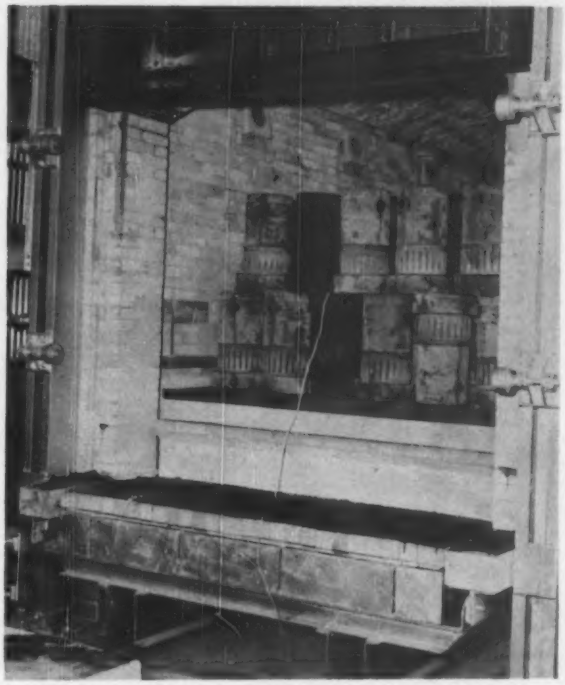


Fig. 9 — Diesel locomotive cylinder liners prior to removal from furnace after stress relieving.

2) Hold at 1050 F for one hr plus one hr/in. of casting section thickness. Most castings are held 2 hr.
3) Cool at a rate not to exceed 100 F/hr to 550 F.
4) Air cool.

Stress relieving at 1050 F causes no change in structure or hardness, and has only the effect of relieving stresses set up in the casting process. Both ductile and gray iron castings may be stress relieved. Castings which tend to distort in or after high speed machining operations or castings which must be machined to close tolerances are generally stress relieved.

Castings may be stress relieved at temperatures from 900-1200 F. With unalloyed gray iron, at temperatures above 1050 F you begin to soften the castings as well as stress relieve.

Higher Temperature Stress Relief

Higher temperature stress relief is the next type of heat treatment. Figure 9 shows a load of diesel locomotive cylinder liners prior to removal from the furnace after stress relieving. These castings are made of a highly alloyed gray iron. The tensile strength of this iron remains about the same after stress relief. The cycle used is:

1) Heat to 1180 F at a rate not to exceed a minimum of 7 hr.
2) Hold for 4 hr at 1180 F.
3) Cool from 1180 to 1080 F at a rate not to exceed 50 F/hr.
4) Cool from 1080 to 200 F at a rate not to exceed 100 F/hr.
5) Air cool.

The microstructure of a cylinder liner at 500× etched with 2 per cent nital is shown before stress relief in Fig. 10, and the same casting after stress relief in Fig. 11. The casting was 255 Bhn as-cast, and the structure was short graphite flakes in a matrix of pearlite. After stress relief the liner was 217 Bhn and the pearlite matrix is somewhat coarser. This stress relief is to remove internal stresses, and also it improves the uniformity of hardness in alloy iron castings. The casting with 255 Bhn as-cast was softened to 217 Bhn, while a casting with 223 Bhn as-cast was softened to 212 Bhn.

Low Temperature Annealing

1) Heat castings uniformly to 1300 F in a minimum of 6 hr.
2) Hold for 2 hr at 1300 F.
3) Cool at a rate not to exceed 100 F/hr to 550 F.
4) Air cool.

Low temperature annealing is used for castings which contain no carbides (cementite) as-cast. About 95 per cent of the annealed ductile iron is run on this cycle. Ductile iron annealed on this cycle will meet a specification of 60-45-15 measured in a 1 in. keel block. The physical properties after annealing are in the range of 60-75,000 psi tensile, 45-60,000 psi yield, 24-15 per cent elonga-

Fig. 10 — (left) Cylinder liner microstructure before stress relief. 2 per cent nital etch. 500 ×.

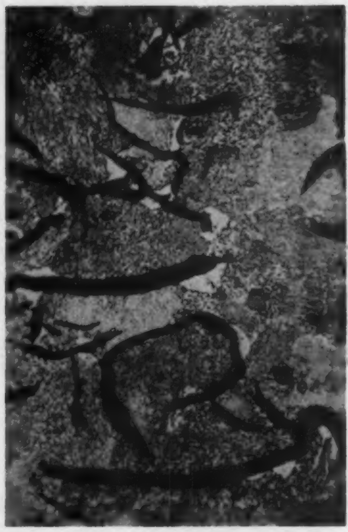


Fig. 11 — (right) Sand cylinder liner shown in Fig. 10, after stress relief. 2 per cent nital etch. 500 ×.

tion and 140-200 Bhn in a 1 in. keel block. Figure 12 shows the microstructure in ductile iron after low temperature annealing at 100 × and etched with 2 per cent nital. This structure is essentially ferritic with some pearlite remaining.

High Temperature Annealing

High temperature annealing is used for ductile castings which contain carbides (cementite) as-cast. As shown in Fig. 13, the microstructure of 100 × etched with 2 per cent nital is graphite nodules in a matrix of pearlite with carbides present.

The cycle used is:

1) Heat castings uniformly to 1650 F in a minimum of 7 hr.
2) Hold for 2 hr at 1650 F.
3) Cool from 1650 to 1300 F at a rate not to exceed 100 F/hr.
4) Hold for 2 hr at 1300 F.
5) Cool from 1300 to 550 F at a rate not to exceed 100 F hr.
6) Air cool.

Holding at 1650 F dissolves the carbides. The microstructure after annealing at 100 × etched with 2 per cent nital is shown in Fig. 14. This structure shows the graphite nodules in a ferritic matrix. High temperature causes some scaling and distortion. The company anneals few castings using this cycle. If the unalloyed gray iron castings are annealed on this cycle the following results are obtained:

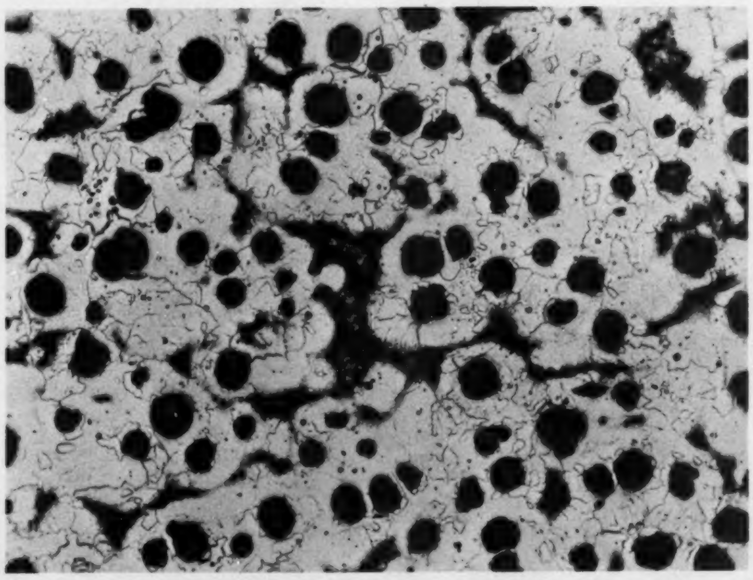


Fig. 12 — Ductile iron microstructure after low temperature annealing. 2 per cent nital etch. 100 ×.

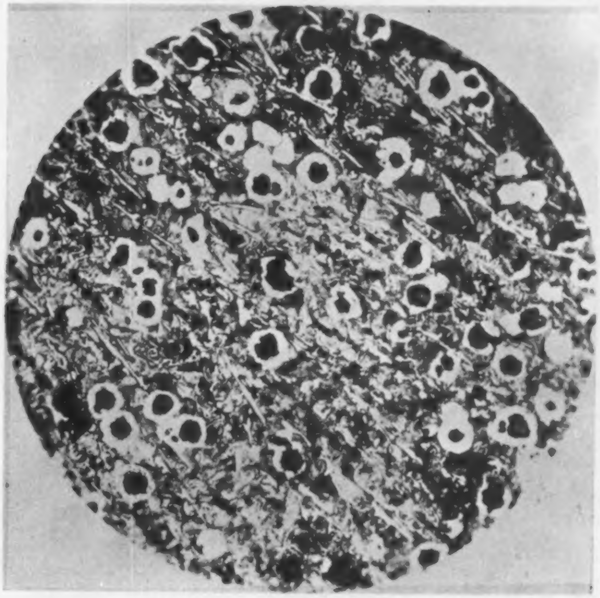


Fig. 13 — Ductile iron microstructure after high temperature annealing, showing graphite nodules in a pearlite matrix with carbides present. 2 per cent nital etch. 100 ×.

	Before	After
1.2 in Bar	30-35,000 Tensile	16-21,000 Tensile
Castings	180-200 Bhn	130-140 Bhn

Normalizing

1) Heat to 1650 F.
2) Hold 2 hr at 1650 F.
3) Cool a maximum of 200 F/hr to 1450 F.
4) Air quench from 1450 F.

The normalizing treatment may be used to produce a structure of 70-80 per cent pearlite in castings which contain an excessive amount of cementite of ferrite as-cast. At present the company is normalizing only ductile iron castings, and this is being done in the small one ton capacity furnace.

Quenching and Tempering

1) Heat uniformity at 1650 F in a minimum of 7 hr.
2) Hold for 2½ hr at 1650 F.
3) Quench in moderately agitated oil.
4) Temper for 2 hr at 900 to 1200 F, depending on the desired physical properties.
5) Cool from the tempering temperature to 550 F at a rate not to exceed 100 F/hr.
6) Air cool.

Quenching and tempering is performed on castings to produce a desired structure and hardness.

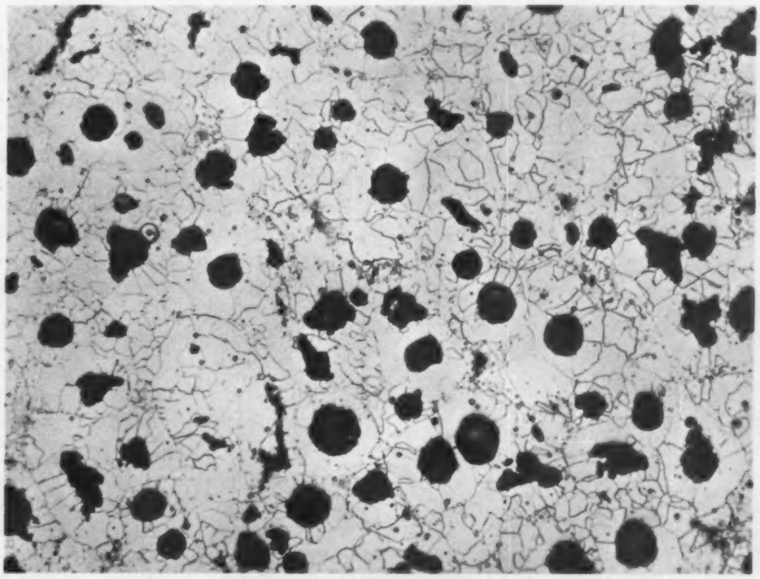


Fig. 14 — Graphite nodules in ferritic matrix after annealing. 2 per cent nital etch. 100 ×.

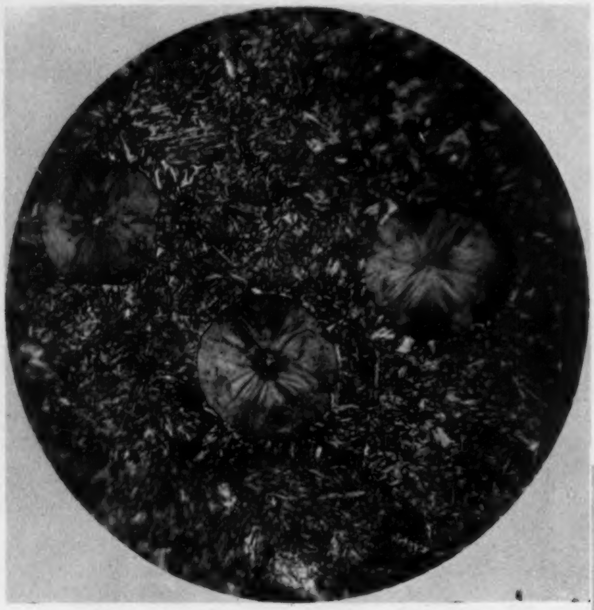


Fig. 15 — Ductile iron as-quenched microstructure. 2 per cent nital etch. 500 ×.

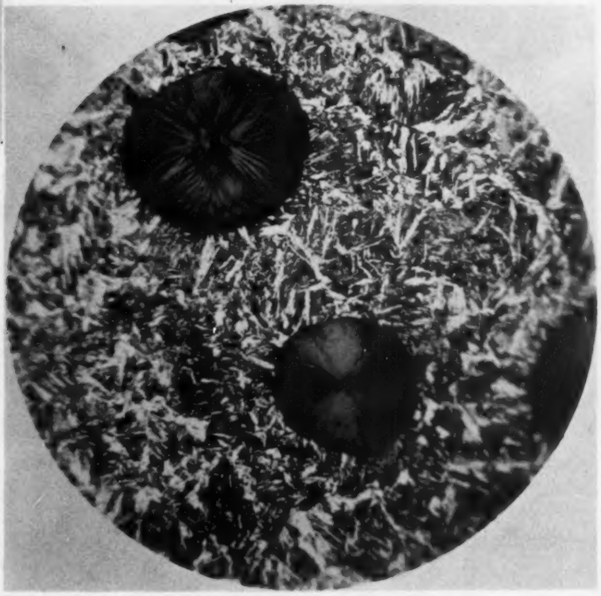


Fig. 16 — Microstructure after tempering. 2 per cent nital etch. 500 ×.

Figure 15 shows the microstructure of ductile iron as-quenched at 500 × etched with 2 per cent nital. The structure shown is graphite nodules in a matrix of martensite. The hardness as-quenched is generally Rockwell C 54-58. By tempering for 2 hr at 1025 F the company meets a specification of 100-75-04 in a 1 in. keel block with 235-280 Bhn in the casting. Actual properties were 133,750 psi tensile, 105,750 psi yield and 5.5 per cent elongation. The microstructure after tempering at 500 × etched with 2 per cent nital is shown in Fig. 16. This structure shows graphite nodules in a matrix of tempered martensite.

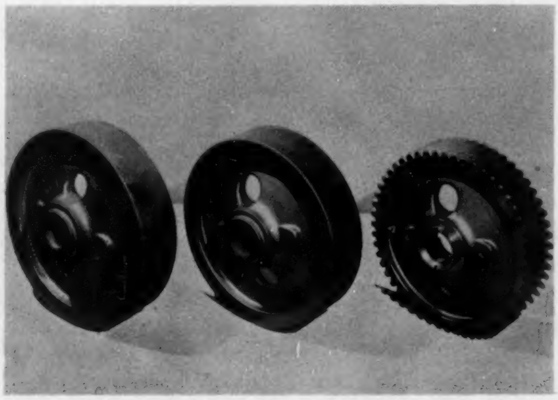


Fig. 17— Timing gears of gray iron tempered to 235-277 Bhn.

Had the tempering temperature been 975 F instead of 1025 F the company would have met the specification of 120-90-02 in a 1 in. keel block with 269-332 Bhn in the castings. Actual properties were 140,000 psi tensile, 116,500 psi yield and 4 per cent elongation.

Gray iron castings such as the timing gear, shown in Fig. 17, may also be quenched and tempered. This casting is tempered to 235-277 Bhn. The structure develops both wear resistance and strength. During the past few years there has been a pronounced increase in the number of castings which receive some type of heat treatment.

PHENOLIC RESIN BOND IN SOLID SAND CORES

by H. K. Salzberg and J. J. Greaves

ABSTRACT

For the ten years or more during which phenolic resins have been available for cores and molds, a working knowledge of their properties has been well established in foundry core rooms using them. This period has also been one of gradual evolution during which grades of resin to meet varying requirements have emerged. Both laboratory and foundry experience are drawn upon in presenting data as to steel sand core mixes, green strength factors, release problems, curing costs and the interface gas factor, with attention given to cores cured in the oven or dielectrically.

INTRODUCTION

The phenolic resin bond began to gain acceptance in foundry core rooms some 15 years ago. In 1951 their adoption was sufficiently wide to justify the presentation of four papers at the Steel Founders' Conference by representatives of foundry organizations that had adopted the resin for at least some of their core work. But long before these dates phenolic resins came into use for bonding abrasive grains, particularly alundum in resinoid grinding wheels.

It would seem that the allied interests of the grinding wheel industry and the foundry industry would have suggested the phenolic resin bond for sand cores long before the application was actually made. However, the explanation for this lag is simple enough when one realizes that the resin bond in grinding wheels, though phenolic in nature, is attained from the acid-catalyzed novolac or two-stage type of resin; whereas the core binder is a water solution of an alkaline-catalyzed single-stage resin, which did not arrive on the industrial scene until some three decades after commercialization of the two-stage resin.

Of interest to most foundrymen is that the resins for shell molding are derived from the grinding wheel resins and not from the more recent core resins, to which this paper will be limited.

Actually it was urea-formaldehyde of the thermosetting resin group that first brought synthetic binders into foundry use with tangible advantages related to its low heat resistance, thus achieving importance in the casting of light metals. With urea-formaldehyde resin having been the pioneer, it was only natural that its counterpart, the phenolic resin of high heat resistance, should be investigated, first by the curious and then by progressive steel foundrymen. In the past three or four years the more dramatic procedures for hardening cores by gassing or by air-setting have taken the stage. However, coremaking and core usage in steel foundries have such greatly varying requirements that a review of the characteristics of the phenolic resin bond appears to be in order, especially in view of the continued use of these binders.

H. K. SALZBERG and J. J. GREAVES are with Borden Chemical Co., Bainbridge, N.Y.

FIFTEEN-YEAR CHRONICLE

The first reference in the TRANSACTIONS of the American Foundrymen's Society to phenolic resins as core binders appeared in 1944 as an article by Morgan,[1] wherein the resin was compared with linseed oil with respect to green strength, baked strength and hardness of core, baking characteristics, hot strength properties, gas evolution and to the use of release agents. However, the data were obtained on core mixes containing more resin than oil, whereas current mixes are usually formulated with less resin than the oil it might replace.

A paper presented to the Society in 1949[2] disclosed the properties of phenolic resins as offered for core bonding at that time, with data on green and baked core properties, their dependence upon the moisture content of the sand mix, the increase in green strength as the core stands in the air, baking characteristics, the retained strength of burned cores and typical mix formulas with costs. McMillan and Wickett[3] expanded upon the importance of the cereal-to-water ratio in phenolic resin cores, upon the effect of kerosene on core physical properties and upon the importance of the mulling cycle.

Greenlee[4] confirmed the importance of the cereal-to-water ratio and the detrimental effects of release agents on core physical properties, and included data on strike-off characteristics of resin-bonded core sand.

Subsequent to these early investigations, phenolic resins were included as core binder in studies of the hot tearing of steel castings[5] and in veining tendencies,[6] but without directly relating these defects to the core binder. However, Middleton[7] compared phe-

nolic resin cores with linseed oil cores as to the hot tearing of a steel test casting, and found equal occurrence of tearing for the two types of core in small castings, with a small advantage for the linseed oil cores in the larger casting.

Recent Investigations

More recently, the physical properties and strength specifications for the purchase of phenolic resin core binders have been disclosed by one steel foundry;[8] and Shumaker[9] published information on the bulk handling and storage of liquid resin binders, including the phenolic type. A useful table shows how the viscosity of phenolic resin increases as its temperature decreases. One would have expected to find reference here to the advantageous practice of cooling the resin to the range of 50-60 F at its source, before shipping, to thus prolong its storage life at the foundry.

Schubert[10] evaluated five different commercial phenolic resins for baked strength, the effect of high humidity on core strength, and gas evolved from unit weight of core at 2500 F. The results, applicable to the baking of phenolic resin cores, showed that

1) There was an optimum baking time and temperature for each resin.
2) Baked strength holds up well on overbaking.
3) Exposure of baked core to an atmosphere of high humidity causes less decrease in strength if the core had been baked at the optimum temperature (usually 450 F).
4) Baked cores, reheated and tested for strength at 250 F, were weaker by 20-45 per cent.
5) Gas evolution was less from cores baked at 450 F than from cores baked at lower oven temperatures.

Later, Schubert[11] showed that a cubical test core attained the temperature of boiling water at its center somewhat quicker when bonded with phenolic resin than when bonded with core oil. The temperature rise within the core, following driving out of the water, reached a level substantially higher than the temperature of the oven atmosphere surrounding the oil sand core, attributed to the exothermic curing of the oil bond. The resin-bonded core did not attain a temperature higher than the atmospheric oven temperature, indicating no exotherm in the resin core during this stage of the cure.

It is suggested by us that, since phenolic resins of this type are known to possess considerable exotherm potential, the exotherm stage of the cure in this experiment occurred during the earlier stages of the heating up of the core. To demonstrate the need for oxygen in curing the oil sand core, the test core was heated to oven temperature in an atmosphere of nitrogen. It failed to acquire any strength, whereas the resin core attained baked tensile strength of 135 psi when cured in the absence of oxygen.

The British Foundrymen's Subcommittee T.S. 30 reported in 1952[12] the results of the experience of 30 foundries with thermosetting resin core binders, including phenolic resins. With respect to the performance of either liquid or dry forms of phenolic resin, an approximate equivalence to linseed oil was reported as to bench life on the sand mix, resistance of the core to overbaking, resistance of the core to deterioration in storage, destruction of the core by heat of the metal, ease of knock-out of core and casting finish. The report, however, is not broken down by metals, and we therefore suggest some degree of reservation as to the pertinence of the conclusions to steel castings.

PHENOLIC RESIN BOND GENERAL CHARACTERISTICS

Definitions of phenolic resins relating to the chemical reactions involved in their preparation have been given in these AFS TRANSACTIONS,[1,2] and will not be repeated here. Instead a brief review of the main characteristics of the bond and how it is formed will serve as introduction to the data presented.

One-step, liquid phenolic resin core binders, as a class, are water-soluble and thermosetting. They are curable by drying and heating to a hard state, which is adhesive to the silica surfaces of sand grains, resistant to water and solvents and burning to gases and carbon without melting and without leaving any significant amount of ash behind. Thus in the sequence of going from the sand mixture to casting, the resin disperses in the water of the core mix, dries on the sand grains, hardens in the oven and burns out in the mold. This basic description of what happens might be enlarged to advantage in our understanding of certain important points relative to the use of this bond in cores.

Water Solubility

The water dilutability of liquid phenolic resin or the solubility of one-step dry resin powder in water are changing properties, slowly diminishing as the resin ages. This happens because the resin, being thermosetting, slowly advances in cure even at room temperature. Liquid grades thicken to an unusable state in 4 to 6 months at room temperature; dry grades become insoluble in 6 to 8 months, depending upon the actual storage temperature.

However, within these time periods the core making efficiency of either type remains undiminished by changes which slowly take place. Resins, liquid or dry, are usable for much longer periods than indicated above, when they are stored under refrigeration. Liquid resin begins to lose strength at the age at which a separation of resin and water becomes distinct. One-step dry resin powder begins to lose its strength when a sample refuses to dissolve completely in an equal weight of water.

The Cured Resin

The cured phenolic resin bond is brittle[13] and of a high degree of hardness. Plasticizing or toughening

are indicated as improvements in bonding the more fragile cores.

This is sometimes approached by including in the core mix a small amount of core oil or alkyd resin, or by adding glycol plasticizers in an amount minor compared to the resin present in the mix. The bond is not completely resistant to moisture vapor, but the same is true of even the pure linseed oil bond.[14,15] Cores are best stored in dry atmosphere and not held overly long in green sand molds. Thermosetting resins, as a class, might be defined as agents which serve to increase the water resistance of the cereal binder also present. Their resistance to solvents is of some consequence when the cores are subsequently coated with washes containing alcohol or oil.

The Silica-Resin Bond

Adhesion of the phenolic resin to silica and to other refractories has received attention by Taylor and co-workers;[16,17] the results applying however to shell molds and cores. Adhesion under conditions prevailing in the forming of cores from water-containing sand has received less attention. Discoveries in non-aqueous sand, as characteristic of shell-molding sand, cannot safely be applied to cores bonded from water solutions of resin and cereal. The bond in solid cores for steel castings is primarily one of an interface of cereal binder with silica, and it would be presumptuous to apply directly the data which have been published on straight resin-to-sand adhesion.

Whether, in a sand core, failure occurs in the resin-cereal bond or at the interface between sand grain surface and bond is not known. If the failure is interfacial, a study of the molecular structure which prevails on the surface of the sand grain, on the one hand, and of the adhesive bonds which can be predicted as present in resin-cereal, on the other hand, should be rewarding in the continuing objective of reducing the amount of total binder which must be used to obtain sufficiently strong cores. The fine structure and molecular characteristics of the surface of the sand grain is suspected to be of importance in the bond strength of resin-cereal cores, and may some day be the subject of investigation.

SAND FACTORS AND TESTING

There are sand factors which to date take precedence over the surface factors when it comes to making good cores. These relate to average grain size, grain size distribution and to shape of grain; the latter determining in large part the degree of packing, or the density and therefore the strength of the core. It is therefore of great importance that comparative tests of different core materials be made on the same sand, and preferably on the sand of a single shipment. A further refinement, which eliminates the sand factor in testing, is to blend a good supply of the core sand in use at any one foundry by dry mixing a ton or two from a typical shipment, and setting this aside for use only in research and control work. The practice of also setting aside shelf samples of each shipment of resin core binder for possible later reference is also to be recommended.[18] These samples are best stored in an area where the temperature does not exceed about 70 F.

Response to Heat

The thermosetting nature of phenolic resins directs its application to the curing of cores in either convection or electronic ovens. Apply heat by either source and the bond cures and hardens, regardless of the presence of the other usual core ingredients. Once cured it stays cured during whatever subsequent operations are applied to the core. The bond is not soft in the cooling core, and does not soften during heat drying of core paste or wash. It does not melt when warmed by the incoming metal, but remains hard and rigid until burned out.

An additional property deriving from the effect of heat, but as yet not fully measured in core baking or heating in the mold, is the exothermic nature of the cure. As the resin cures heat is developed, thus speeding both the baking of the core and its decomposition in the mold. This effect is undoubtedly small in the thin unconfined films of resin as they exist in the core, but may, if close measurements were made, account in part for fast baking of the core and for its ready collapse in the mold.

Gases Evolved

The chemical composition of phenolic resins is such as to expect the evolution of both carbon oxides and hydrocarbons from dry sand cores upon pouring of the metal. The relative proportion of these gases depends upon the degree to which oxygen is present in the mold during rise of the metal. Cured phenolic resin contains 80 per cent carbon, 6 per cent hydrogen and 14 per cent oxygen. The complicated reactions which occur in the combustion of this bond depend primarily upon the availability of oxygen.

The degree to which hydrogen and hydrocarbons are oxidized is most difficult to predict in view of the presence in most cores of cereal binder, which is also being simultaneously converted to gases. Locke and Ashbrook[19] analyzed the gas evolved from molding sand containing cereal binder and bentonite, obtaining substantial quantities of carbon monoxide, hydrogen and nitrogen, but the combination of cereal and resin has not been so investigated.

From the practical standpoint of total gas-forming material in the core as it is inserted in the mold, the relatively low amount of phenolic resin required to obtain hard cores indicates less total gas as molten metal contacts core. Also, experience has shown that the burning of phenolic resin under conditions prevailing in the mold does not evolve as much carbon, as such, as does core oil, rosin, seacoal or pitch. Smoke from a phenolic resin-cereal core is at a low level. The chemical nature of the resin, however, results in the evolution of a small amount of formaldehyde, which, together with the combustion prod-

ucts of the cereal, accounts for the acrid nature of the gases experienced at the pouring stations.

Phenolic resins belong to the category of binders which leave but little mineral matter behind on combustion.[20]

Aging Characteristics of Phenolic Resins

The rate of advancement of the liquid resin in storage can be followed by the simple expedient of determining its tolerance for added water, that is, the percentage of water that can be added before precipitation of resin solids. Water can be added to fresh resin in almost unlimited amount, diminishing later rapidly during the first few weeks, then leveling off at lower values after several months.

A typical batch of liquid resin, of the alkaline water-solution type used in foundry core rooms, was observed for changes in properties over a period of 142 days storage at 70 F. The data are presented in Table 1 and Fig. 1. Being thermosetting, liquid phenolic resins slowly advance in cure even at room temperature. The changes are mainly an increase in viscosity and a decrease in water dilutability. Finally, after some months, the resin will have advanced to the stage where no water can be added without precipitating resin solids.

TABLE 1 — AGING RECORD OF LIQUID PHENOLIC RESIN CORE BINDER

	Days Since Manufacture											
	6	14	21	29	35	42	49	56	84	98	111	142
Water dilutability, %	Unl.	2600	1280	1100	690	570	310	260	260	250	150	0
Core Strength												
Green comp., psi	0.55	0.6	0.55	0.6	0.55	0.45	0.5	0.43	0.65	0.55	0.65	0.6
Baked Tensile at 30 min	230	230	230	220	225	265	215	235	210	205	245	235
60 min	240	245	220	235	220	215	230	215	225	195	165	210
Scratch hardness	95	96	97	97	96	92	94	84	94	92	92	95

Unl. – Unlimited

Core formula: 1% cereal, 1% resin, 0.5% kerosene, 0.025% release agent in N.J. silica sand, Gfn 70, at 5% moisture content, or coded: N.J. 70/5/1/1L/0.5/0.025.

Core strength and hardness values are averages of three test specimens.

Fig. 1 — Water dilutability decrease in liquid phenolic resin stored 142 days at 70 F.

Following this period, water begins to separate out as a layer on top of the thickened resin. However, at the stage at which water tolerance has just become nil, the resin still maintains its full core-binding strength, in cores of typical resin-cereal-water composition.

SANDS AND THE PHENOLIC RESIN BOND

The factors which determine the bond strength of green and baked cores present a most formidable challenge to one who would venture to develop laws to cover the general case. One must take into consideration many things—the specific surface of the sand grains, their degree of packing, distribution of the bond in the fine capillary points of contact between grains, the chemical bonds which determine the interface between binder and silica, the stress-strain relationships in the adhesive itself and the manner in which stress is applied to the sand and to the core in arriving at strength values.

Any investigation of the fundamentals of the bond existing in solid core practice should be directed to the resin-cereal-water combination rather than to the resin alone.

For practical purposes it is of first importance in the core room to know that sands of different origin differ widely as to both green and baked properties in the same core mix formula. This holds for the phenolic resin-cereal bond as it does for other materials. Each of the earlier investigations of phenolic resin core binders was confined to the use of a single sand. To extend the information on this bond, cores were made on a typical resin-cereal formula with sand type the only variable. The standard laboratory test formula is:

Sand, dry, grams	4000
Cereal, grams	40
Mix 2 min	
Water, cc	160
Resin, liquid, grams	40
	(20 grams if dry)
Mix 5 min	
Kerosene, cc	20
Release, dry or liquid	
gram	1
cc	2
Mixing cycle	Dry, 2 min Water & resin, 5 min Kerosene & release, 2 min

The green sand is discharged into a container, covered and, when all sand mixes in a test series have been prepared, the core specimens are formed and baked. Thus, there is no long holding of the green sand before forming the test cores. A prolonged holding period here may influence the test results, if the sand mix contains an ingredient which has a premature curing action on the resin at room temperature. Complementing the precaution is that of preventing the green sand or core from superficially drying out before forming or baking the specimens.

Three cores are made and baked from each mix,

and the strength values averaged. The green strength values are in terms of green compression on the standard 2 in. cylinder specimen. Twenty different sands were screened to obtain the AFS fineness number (Gfn). In Table 2 they are listed by commercial names in ascending Gfn order. The core formula varied from that above in having only 0.5 per cent of resin, so that no core would be too strong for the strength machine.

By subjecting the test values of Table 2 to statistical analysis, a positive correlation index of 0.7 is obtained between Gfn of all the sands and green compression values. Since an index of 1.0 signifies perfect correlation, this analysis points to the existence of factors other than fineness of grain to affect the green strength of the cores. Closer inspection of the sand list and application of knowledge concerning the characteristics of these sands, other than grain size, clearly shows that variations in purity with respect to silica and in grain shape and size distribution prevent an exact equating of grain size alone with green strength.

TABLE 2 — SAND GRAIN FINENESS AND CORE STRENGTH

Test Core Mix	
Sand, dry, grams	4000
Cereal, grams	40
Water, cc	160
Resin, liquid, grams	20
Kerosene, cc	20
Release, liquid, cc	2

Sand	Gfn	Green Comp., psi	Baked Tensile Strength, psi
Provincetown	24	0.78	128
Rawdon (Canada)	35	1.01	103
New Jersey 30	41	0.50	103
Kingston (Canada)	45	0.42	157
Manistee	46	0.36	180
50/70 Testing	50	0.40	235
Bond	51	0.43	205
Michigan City	52	0.40	190
New Jersey 40	52	0.41	170
Crude silica	52	0.82	166
Ottawa Banding	55	0.64	260
Festus	58	1.18	132
Wilmot	59	1.07	100
New Jersey 80	63	0.74	104
McConnellsville	82	1.12	86
Whitehead E	90	0.68	98
McConnellsville	97	1.08	98
Juniata Bank	109	0.95	78
McConnellsville	113	0.90	92
Providence River	117	1.28	143

The same statistical procedure applied to all sands, and baked strength values results also in a correlation index of 0.7, but here the correlation is negative. The interpretation is that as Gfn increases the baked strength generally increases when no change is made in the core mix formula. Here also the correlation is not perfect, factors other than grain size exerting an influence to prevent a perfect fit of baked strength to grain size, and, therefore, incidentally to grain surface area.

From the data presented we can generalize that, over a number of sand types, green strength values will probaby (in 7 out of 10 times) increase by switching to any finer sand, and that the baked strength will probably decrease (by the same odds). The correlation index of 0.7 is obtained from the data of Table 2, when green strength is matched against baked strength. This permits a cautious generalization that sand mixes of higher green strength are apt to show lower baked strengths under the same degree of ramming and core baking, and with no change in core mix ingredients other than sand. This approximate but quick method of estimating the correlation between two variables is illustrated in Fig. 2.

Thus, if the target of investigation of bond strength is to be, for instance, the interface of the silica grain with resin cereal in cores of sand of different origin, it is imperative that the variables of grain size, size distribution, shape and impurities, be phased out. This is to permit dealing with the uncontaminated silica surface, as it may vary in molecular nature from one geologic source to another. These variables must be understood and weighed in any study leading to modification of the bond interface itself.

Resin to Sand Ratio

There are good technical reasons in the foundry for avoiding excessive binder in core mixes, and these reasons can serve to support the obligation of avoiding also excessive costs in purchasing. Too many cores have been made with more resin in the mix than is necessary. The dominating factor determining the strength of core, both green and baked, is the ratio of water to resin solids plus cereal, and not the ratio of resin to sand. In cores to be oven baked, adjustment of core mix formula to attain maximum baked strength is first sought in the determination of water required.[3]

For most cores, a combination of 0.5-1.0 per cent of resin with 1-2 per cent by weight of cereal binder is adequate, if the moisture content is adjusted to give the required baked strength. However, electronic baking is more economically done at lower core moisture, which is therefore made up by a small increase in resin content.

That the solids content of liquid resin is, within limits, somewhat inconsequential to core strength in the presence of cereal binder was shown by a series of core oven baking experiments in the authors' company's laboratory (Table 3). Here a commercial grade of phenolic resin was diluted stepwise with water, then used to bond cores on three different sands containing also 1 per cent of cereal binder, and keeping moisture content constant at an even 4 per cent. Within the range 60.7 per cent to 65.7 per cent solids baked strength and hardness of core did not change materially.

This leads to some doubt as to the importance of a solids range specification on liquid phenolic resin binder. Instead we are induced to return to a consideration of the fundamentals of adhesion that operate in the sand core, that is to a realization that

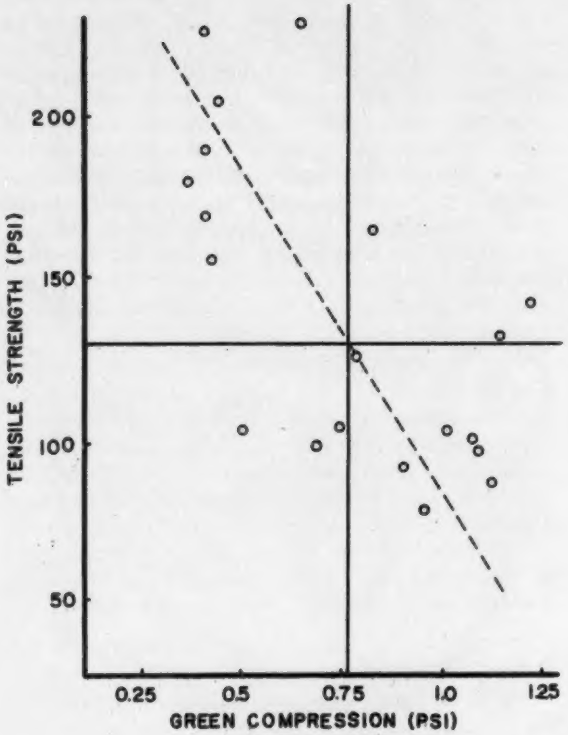


Fig. 2 — Correlation between green and baked strengths.

the chemical makeup of the resin rather than the amount used primarily determines its contribution to the strength of the core.

TABLE 3 — BAKED CORE STRENGTH AND HARDNESS

Phenolic Resin of Varying Solids Content
Sand Mix

Sand, grams	4000
Cereal, grams	40
Resin, liquid, grams	40
Water, cc	160
Kerosene, cc	20
Release, dry, grams	1

Sand Type:	New Jersey 80			Wedron 70			Mich. City: Juniata Bank (1:1)		
Resin									
Solids, %	65.7	60.7	55.1	65.7	60.7	55.1	65.7	60.7	55.1
Baked Tensile, psi									
At 400 F									
30 min	210	225	220	362	360	357	260	205	205
45 min	210	215	220	367	363	332	235	220	240
60 min	200	190	200	356	355	300	245	235	220
Scratch Hardness									
At 400 F									
30 min	94	94	94	95	95	98	96	96	96
45 min	90	90	90	98	98	98	96	96	96
60 min	93	93	93	98	98	98	96	96	96

Release from Core Box

Inspection of the commercial core mixes of Table 6 shows that most resin mixes include a release agent, carried by kerosene or fuel oil and added last in the mulling cycle. Often the release and oil are premixed, but they can be added separately if the man at the mixer prefers to do so. Here is some information, based upon experience, concerning release agents, that bears upon the physical properties of the green and baked core.

If one first visualizes that the release agent is drawn preferentially from the sand mix to adsorb by molecular forces as a thin layer on the surfaces of the core box, the effectiveness of the small amount of material in the sand is understood. The need for only a thin coating of release, replenished from the sand on each contact in the core box, is a deterrent to overadding release at the muller. The importance of a correct balance between release and other ingredients in the sand mix is evident from the observations:

1) The nature of release agents for phenolic resins is such as to reduce the green strength of the sand.

2) Excessive release may also reduce the strength of the baked core.

3) Excessive release will cause more sand to stick to core box surfaces than if the optimum amount is used.

4) The proper amount of release is dependent upon a) the resin content, more resin requiring more release, b) moisture content, more release being required at higher moisture contents and c) the non-resin ingredients, an increase in cereal permitting a decrease in release, whereas fines, such as silica flour or fine sand usually requiring more release.

Fortunately, a convenient criterion of the release properties of a sand mix while in certain mullers is at hand, for it is demonstrated that if the muller wheels become shiny and do not pick up sand grains, the sand will have good release properties in the core box. It has been well established, however, that resin sand will not release well from shellacked wood, but does release from aluminum pigmented coatings and from lacquer coated wood. An interesting alternative to kerosene release partings is the inclusion of core oil with phenolic resin binder (Mix K, Table 6).

Electronic Curing

Two core mix formulas being cured by high frequency current are listed in Table 6. For some time after the introduction of phenolic resins uncertainty plagued both resin producer and foundry engineer as to whether this binder could be cured in the same dielectric units which had been adopted for the curing of urea-formaldehyde resins. The confusion was understandable from the known requirement of more heat for curing phenolic resins than for curing urea-formaldehyde resins.

TABLE 4 — STRENGTH PROMOTERS FOR ELECTRONICALLY CURED CORES

Phenolic resin and 1% cereal as binder, 4% moisture
Values in tensile strength, psi at room temp.

Illinois Silica Sand (Gfn 70) with 0.65% phenolic resin powder

Sand Replacements, %	**0**	**1**	**2.5**	**5**	**10**	**20**
Mich. City Lake Sand	228	—	—	245	270	290
Burnt Molding Sand	205	290	203	240	—	—

Sand Additives, %	**0**	**0.1**	**0.2**	**0.5**	**1.0**	**2.0**	**3.0**
Fire clay 1	210	—	223	250	305	—	—
Aluminum silicate	198	192	230	240	226	—	—
Graphite	184	—	180	221	212	—	—
Mixture of above 3 components*							
in Ill. Silica Sand	210	—	—	—	365	367+	367+
in Mich. City Lake Sand	244	—	—	—	271	250	250
in N.Y. McConnellsville Sand	184	—	—	—	184	190	178

Mich. City Lake Sand Gfn 55 with 1.0% liquid phenolic resin

Sand Additives, %	**0**	**0.2**	**0.5**	**1.0**	**2.0**	**3.0**
Fly ash	168	205	200	223	—	—
Same mixture as *, above	190	—	—	173	237	248

Test cores cured for 2 min in a laboratory electronic oven at 4000 v, 8 mc, ¼-in. air gap.

This problem has since been resolved by the discovery that there are differences in sands with respect to their response to the high frequency current, and by finding additives that make a good conductor of a poor conducting sand.

Boric acid is the universally used high frequency current carrier in cores bonded with urea-formaldehyde resin, and was therefore naturally included in the first phenolic resin cores to be dielectrically cured. Uneven results were experienced. Laboratory tests often showed a sharp drop in dry strength of dielectrically cured cores when boric acid was included with phenolic resin as binder. Other additives, which would be expected to enhance the current carrying capacity of the core, as it approaches dryness, were investigated.

Materials which have been shown to be effective in this way, when added to pure silica sand, are molding sand, clay, graphite, fly ash, and aluminum silicate. Others no doubt will be found. Also, as shown in Table 4, a partial replacement of pure silica sand by a less pure lake sand substantially increases the strength of the dielectrically cured core.

These test data on the individual additives led to the compounding of a mixture of the more effective materials, and its effect is also shown in Table 4 and Fig. 3. Of doubtful value in our tests were iron oxide and mica.

SHOP PRECAUTIONS WITH PHENOLIC RESINS

The first attack of contact dermatitis in a core room, an unrecorded event in history, probably occurred when the first cores were made by hand. The problem has been with the industry ever since, at times being acute and at other times losing importance. With the increased use of resin core binders, the dermatitis problem has intensified to cause concern among coremakers and their employers.

Water soluble phenolic resins necessarily contain some residual free phenol and formaldehyde, which are probably the actual irritants. Resin suppliers are alert to this problem, and are formulating the resins with low limits on the amount of free chemical present. Liquid phenolic resins being made today contain less than 1 per cent formaldehyde. The free phenol content cannot be accurately determined, but appears to be in the range of 3-5 per cent.

Dry powder resins contain lower amounts of these free chemicals. Resin manufacturers are prepared to recommend additives at the muller which have a neutralizing effect on free formaldehyde and phenol. Cereal binder itself has the property of absorbing these chemicals.

Several hundred foundry call reports were reviewed in order to arrive at an approximation of the proportion of resin users who have experienced dermatitis from the core mix. The record by years is shown in Table 5, which is made up from reports of experience with several commercial phenolic resins, liquid or dry, of the same general type and formulation, but not identical.

The record shows that dermatitis occurred with varying frequency, with no cases reported in two different years, to an incidence as high as six in 50

TABLE 5 — DERMATITIS INCIDENCE IN FOUNDRIES USING PHENOLIC RESIN CORE BINDERS*

	Foundries Reporting Dermatitis	No. of Steel Foundries Visited and Using Phenolic Resin
1950	0	36
1951	2	17
1952	4	37
1953	5	66
1954	6	50
1955	5	45
1956	0	33
1957	2	16
1958	1	12
1959	2	21

* Commercial grades, liquid and dry.

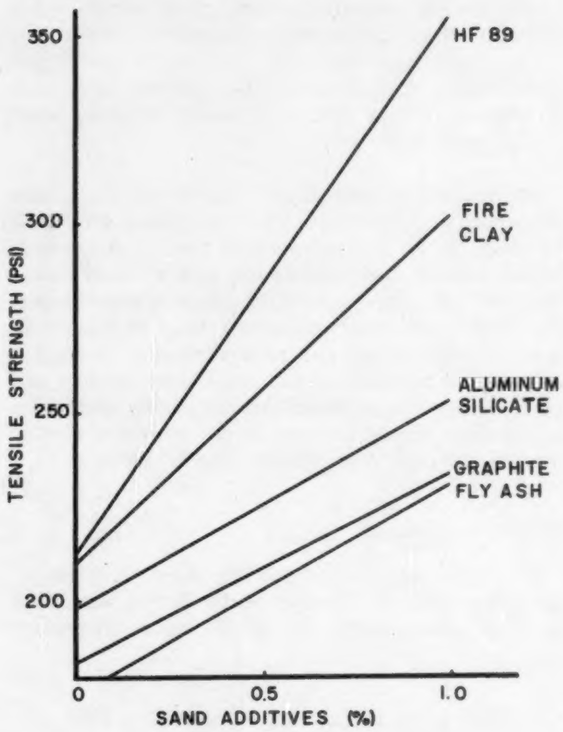


Fig. 3 — Strength promoters for electronically cured cores.

TABLE 6 — STEEL FOUNDRY CORE MIXES EMPLOYING PHENOLIC RESIN

			Ingredients in % by weight of sand-plus-mineral additives									
Sand, dry	Gfn	Moisture Content	Cereal	Resin, Liquid	Resin, Dry	Kerosene	Release	Mineral Additives	Oven Temp., F	Core Forming	Steel Type	Casting
A. New Jersey	60	4.5	2.2	—	1.1	0.4	—	Bentonite, 0.2	400	Rammed	Carbon	Various
B. Nevada	70	3.4	0.25	0.25	0.5	0.25	sand oil	—	350	Blown	Alloy	Various
C. Gfn	35	3.8	1.0	1.7	—	0.75	0.1	Silica, 12.5 Clay, 0.5 Iron oxide, 1	500	Blown	Valve	(Pouring cup)
D. Pettinos	70	4.2e	0.75	1.75	—	1.25	0.2	—	450	Blown	Alloy	Magnet
E. Hatfield	52	5.6	1.5	—	1.0	0.75	0.07	—	410	Rammed	Alloy	Valve
F. Rockwood-Molding (1:1)	—	4.8e	1.0	1.9	—	0.4	0.1	Boric acid, 0.5 Bentonite, 0.5	Elec.	Rammed	Alloy	Wrench
G. Reclaim	—	3.1e	1.0	1.7	—	0.7	0.1	—	450	Rammed	Alloy	Magnet
H. New Jersey	60	6.6e	2.2	0.9	—	0.5	0.1	Silica, 16 Iron oxide, 1.4	Elec.	Rammed	Carbon	Various
I. —	48	5.0	2.0	—	1.0	2.2	0.3	Silica, 2 Fire clay, 1	375	Rammed	Carbon	Various
J. —	60	3.3	1.0	1.7	—	1.0	0.5	Silica, 2 Clay, 1 Iron oxide, 1.3 Bentonite, 0.8	400	Rammed	Carbon	Various
K. Portage	75	7.0	0.5d	0.25	—	core oil	0.5	Silica, 7.5 Bentonite, 1.5	450	Rammed	Carbon	(Gate cores)
L. —	50	6.0	1.5	1.0	—	0.4	0.5	Silica, 10	400	Rammed	Low C	Railroad

e—estimated, other moisture values determined. Elec.—Electronic curing. d—dextrin

foundries in one year (1954). The record does not show any strong indication that the problem is either becoming more acute or is diminishing. Supervised patch tests show phenolic resins to be in the category of primary irritants, and it is the purpose here to remind the reader of the simple preventive measures that are available.

Contact dermatitis manifests itself in one of three ways: 1) as red, itchy skin, 2) as small blisters and 3) as dry and cracked skin.[21] An irritating chemical, such as phenol or formaldehyde, has a drying out effect on the skin, and tiny cracks may appear. Bacteria, always present, enter these cracks and cause the skin to exhibit one of the above conditions. Generally dark-skinned, dark-haired workers are less susceptible to irritation than fair-haired, light-skinned persons. This is not always so.[4]

Experience has shown that the prevention of dermatitis is much easier to accomplish than its cure. Strict personal hygiene has proved to be the best preventive. A thorough scrub with soap at the end of the shift will protect most workers.[21] An antiseptic soap is to be recommended[22] even though the chemicals in the resin are, themselves, strongly bactericidal. Protective creams have not proved entirely satisfactory in the core room because the sand abrades away the protective film.

However, if a cream is selected which protects against water-soluble chemicals, and preferably contains a mild acid to neutralize the alkalinity of the resin, considerable protection can be obtained. Sax[23] states:

> "The most popular method for prevention of skin irritation by a chemical is the use of protective creams. These do not give the positive and lasting protection afforded by protective clothing, but this is counterbalanced by the willingness of workers to use them. . . . No single cream provides adequate protection against all types of chemicals. . . . Before applying a protective cream the skin should be thoroughly cleansed, application made before the start of work, washed off before the lunch period, and reapplied after lunch, again washed off on leaving the job."

Obviously, freedom from skin irritation, causable by any material in the core mix, is assured when employee and employer cooperate to prevent its occurrence. The employee practices personal hygiene in regular washups, in using protective creams and in frequent change of work clothes. The employer provides washrooms with ample supply of warm water, antiseptic soap, sanitary drying means and facilities for change of clothes at lockers.

Fortunately skin irritation is the only hazard to be guarded against in the use of phenolic binders. Although the atmosphere at the muller, at the core oven or at the pouring station, contains fumes of formaldehyde and phenol, they are present in amounts far under the maximum allowable concentration. This is evident from analytical data obtained in plants where the resins themselves are made. An investigation made by the Division of Industrial Hygiene and Safety Standards of the New York State Dept. of Labor[24] showed the presence of 1-2 ppm of formaldehyde and 0.22 ppm of phenol in the workroom where the resin was being made. The maximum allowable concentration of either chemical is 5 ppm, as set by the American Conference of Governmental Industrial Hygienists.[23]

PRESENT STATUS IN STEEL FOUNDRIES

The steel castings which are currently being made with solid phenolic resin cores include both carbon steel and alloyed steel castings. Among these are cores for:

Valves	Tank turrets
Car wheels	Chain hoists
Impellors	Fittings
Clutch plates	Magnets
Hardware	Drill bits
Rolls	Railroad

Special cores being made include pouring cups, runner cores and Washburn riser cores. A few core mixes in use in steel foundries employing liquid or dry phenolic resin binders are given in Table 6. The organic ingredients are given in parts by weight to 100 parts of sand-plus-mineral additives. The mineral additives are given in lb/100 lb of sand. Performance characteristics of each mix, as observed by foundry personnel, are recorded in order to throw more light on the action of phenolic resin in the core, both green and baked.

Mix A was used first only as backup sand behind a facing of oil sand, later converted to all resin sand because of uneven baking of the oil and resin sands, with scabbing attributed to underbaked oil sand. Until this mix was perfected, troubles were encountered as to irritation of coremakers' hands, stickiness in wood core boxes and blows in the castings. Core boxes were subsequently lacquer coated.

The burnt core sand is reclaimable by scrubbing at a process cost of $1.75/ton. The high cereal content permitted the inclusion of the small amount of bentonite without sacrifice of core strength and hardness, and obviated the need for a release agent other than kerosene.

Mix B was formulated primarily for fast core production and baking, with low fumes and smoke from the relatively low amount of combustible material in an open western sand. The combination of liquid and dry resin was reported to increase green strength. A commercial sand oil conditioner is used as release agent.

Mix C is mulled in a fast muller on the cycle of 15 sec dry, 60 sec wet and 15 sec release. The sand, being coarse, is closed up with silica flour and fire clay for forming pouring basins and cups.

Mix D is another open sand with low combustibles,

therefore having a relatively high level of release agent, for blown cores for magnet steel.

Mix E is a simplified mix for valve cores, and might be suggested as a basic resin mix to which additives can be made to attain additional room temperature or hot strength properties.

Mix F contains molding sand to give it extra response to curing in an electronic oven, and to provide higher hot strength properties required for smooth finish on steel as-cast.

Mix G is an all reclaim sand mix for core molds, requiring a relatively high level of resin. It was found that the casting finish depended upon the degree of baking to which the cores were carried, that both underbaked and overbaked cores gave inferior casting finish. Cores baked for one hour at 400 F gave the best finish. The mix cost is higher than that for oil sand which it replaced, but, once adjusted to give smooth casting surfaces, was adopted.

Mix H is a strong sand, both green and baked, and when contacted by hot steel. It has been in use for a variety of carbon steel castings since 1955. The silica flour addition was found to increase baked core strength, as well as to serve as usual in improving the as-cast finish. Smaller cores are made from the same mix to which carbonaceous material is added to promote carry of the high frequency current. Some dermatitis was experienced at first among the coremakers.

Mix I gradually evolved from several earlier formulas, eventually resulting in a reduction in hot tearing of thin-walled carbon steel castings. A reversal in the usual order of mulling, namely addition of resin to dry sand before adding water gave a sticky sand. Sticky sand also resulted from too low a moisture content (as also results from too high a moisture content).

Mix J gives a relatively low gassing core, being rich in resin and low in cereal. The release agent is cottonseed oil, and the usual shellac coating on wood core boxes was replaced by lacquer.

Mix K is of interest in comprising both phenolic resin and fast baking core oil. The oil is reported to have improved "lubricity" of the sand, and to retard drying out of sand and core prior to baking. The optimum oven temperature range for phenolic resins is the same as for core oils, and thus combinations of them in the same core mix are not precluded. This is not so with the urea-formaldehyde resins, which are best cured at an oven temperature well under that used for core oils.

This mix also illustrates the compatibility existing between bentonite and dextrin. Gate cores for tank turret castings, are coated with silica wash, strengthened with the same phenolic resin.

Mix L is a sand mix which evolved after much experimentation to find a solution to the dilemma of penetration vs. hot tear contest in producing scrap steel castings. The castings are of 5/8 to 1 1/8-in. wall thickness, weighing 200-500 lb. The mix given produces cores which, when hollowed out and washed with zircon resolved the problem.

(For convenience in listing the composition of a number of core sand mixes, a shorthand system is used in the authors' laboratory, and is respectfully offered as a space-saving suggestion for use in communicating information in re core formulas. The sequence is: Sand/moisture/cereal/resin or oil/kerosene/release/additives indicating the type and fineness of sand, whether the resin is liquid or dry, with ingredients and additives expressed as parts per 100 of sand.

Thus Mix L in Table VI becomes Gfn 50/6/1.5/1L/0.4/0.05/silica 10. A glance at the coded formula indicates the green, baked and hot properties of the core, as well as the cost of the mix.)

REFERENCES

1. W. C. Morgan, "Thermosetting Plastic Core Binders for Ferrous and Non-ferrous Metals," AFS Transactions, *vol. 52*, p. 1317 (1944).
2. H. K. Salzberg, "Plastic Binders for Foundry Sand Practice," AFS Transactions, *vol. 57*, p. 357 (1949).
3. J. E. McMillan and J. A. Wickett, "Phenolic Resin Core Binders. Effect of Core Composition on Physical Properties of Cores," AFS Transactions, *vol. 58*, p. 439 (1950).
4. R. H. Greenlee, "Modern Core Sand Practice," AFS Transactions, *vol. 59*, p. 412 (1951).
5. C. H. Wyman, C. A. Faist and G. Di Sylvestro, "Hot Tear Investigation," AFS Transactions, *vol. 60*, p. 145 (1952).
6. AFS Sand Division Committee, "Veining Tendencies of Cores," AFS Transactions, *vol. 60*, p. 219 (1952).
7. J. M. Middleton, "Influence of Molding Materials on Hot Tearing," AFS Transactions, *vol. 61*, p. 167 (1953).
8. E. G. Vogel, "Purchase Specifications for Commonly Used Steel Foundry Mold and Core Sand Binders," AFS Transactions, *vol. 66*, p. 125 (1958).
9. T. P. Shumaker, "Bulk Storage and Handling of Liquid Core Binders," *Foundry, vol. 85*, no. 4, p. 152 (1957).
10. C. E. Schubert, "Some Properties of Phenolic Resin Core Binders," *Foundry, vol. 82*, no. 12, pp. 100, 248 (1954).
11. C. E. Schubert, "What Happens When a Core Is Baked?" *Foundry, vol. 83*, no. 11, p. 128 (1955).
12. Institute British Foundrymen, "Synthetic Resin Core Binders —A Report," American Foundryman, *vol. 21*, no. 2, p. 51 (1952).
13. F. Quigley, P. J. Ahearn and J. F. Wallace, "Influence of Bonding Materials on Stress-Strain Characteristics of Bonded Sands," AFS Transactions, *vol. 65*, p. 319 (1957).
14. Victor Rowell, "Properties of Sand Cores," *Foundry, vol. 76*, pp. 80, 198 (1948).
15. A. E. Murton, H. H. Fairfield and B. Richardson, "Core Oil Evaluation Method," AFS Transactions, *vol. 59*, p. 276 (1951).
16. R. G. Powell, C. M. Adams and H. F. Taylor, "Research in Shell Molding," AFS Transactions, *vol. 62*, p. 143 (1954).
17. J. K. Sprinkle and H. F. Taylor, "Adhesion of Phenolic Resin to Refractory Oxides," AFS Transactions, *vol. 65*, p. 300 (1957).
18. F. S. Brewster, "Practical Molding Sand Control," *Foundry, vol. 82*, no. 11, p. 102 (1954).
19. Charles Locke and R. L. Ashbrook, "Nature of Mold Cavity Gases," AFS Transactions, *vol. 58*, p. 584 (1950).
20. AFS Roundtable, "pH Control of Foundry Sands," American Foundryman, *vol. 26*, no. 3, p. 34 (1954).
21. Floyd Van Atta, "Dermatitis Prevention in the Foundry," *Foundry, vol. 82*, no. 5, p. 289 (1954).
22. R. B. Trusler, "New Soap Cuts Industrial Dermatitis," *Foundry, vol. 79*, no. 5, p. 139 (1951).
23. N. I. Sax, *Dangerous Properties of Industrial Materials.* Published by Reinhold, N. Y. (1957).
24. May R. Mayers and Mabel Silverberg, "Health Hazards in the Plastic Industry," *Ind. Bull., vol. 15*, no. 8 and 10 (1936).

ALUMINUM ALLOY WITH HIGH SILICON CONTENT

by E. E. Stonebrook

ABSTRACT

Alloy X392 die castings were developed to provide a combination of characteristics which would best satisfy the requirements of many parts subjected to wear while retaining satisfactory castability and machinability. The nominal composition is 19.0 per cent Si, 0.6 per cent Cu, 1.0 per cent Mg and 0.4 per cent Mn.

Hypereutectic Al-Si alloys have been used to a limited extent for many years, but the better casting characteristics — machinability, mechanical properties, homogeneity of structure and thermal conductivity — have favored the use of hypoeutectic alloys, such as A132, 355 and 380. Adoption of phosphorus refinement of the primary silicon crystals in the hypereutectic alloys, with the accompanying improvement in machinability and reduction in segregation, as well as the need for more wear resistance, have stimulated renewed interest in these alloys.

Alloy X392 is currently being used for production of commercial die castings and experimental sand and permanent mold castings. Parts which appear to be potential applications for alloy X392 die castings are cylinder liners, cylinder blocks, brake drums, clutch plates, sheaves and pulleys.

INTRODUCTION

The desirable properties of hypereutectic Al-Si alloys, such as good wear resistance and low coefficient of thermal expansion, have been recognized for many years, and alloys of this type were developed to exploit these properties.[1,2] These alloys have been used to only a limited extent in this country, but have achieved some success in Europe, particularly in Germany for production of heavy-duty pistons.[3,4]

E. E. STONEBROOK is Rsch. Met., Aluminum Co. of America, Cleveland.

Silicon crystals are the primary phase in these alloys, and these crystals normally are quite large, as shown in Fig. 1, unless solidification is rapid. These primary silicon crystals tend to segregate in a casting because of differences in specific gravity, and also contribute to poor machining characteristics. These disadvantages as well as inferior castability tended to hold back utilization of these alloys.

Introduction of a small amount of phosphorus into a melt will refine the primary silicon, as shown in Fig. 2. This refinement reduces segregation and improves machining characteristics, although carbide tools still must be used.

A patent issued in 1933 covered the use of phosphorus in Al-Si alloys, both hypoeutectic and hypereutectic, to improve frictional characteristics.[5] It was only in recent years, however, that the use of phosphorus to refine the primary silicon, combined with the use of carbide tools for machining, served as an impetus to increased application of the hypereutectic Al-Si alloys. More recently, this interest was stimulated in this country by the need for wear-resistant aluminum alloys for light weight engines, brake drums and other parts.

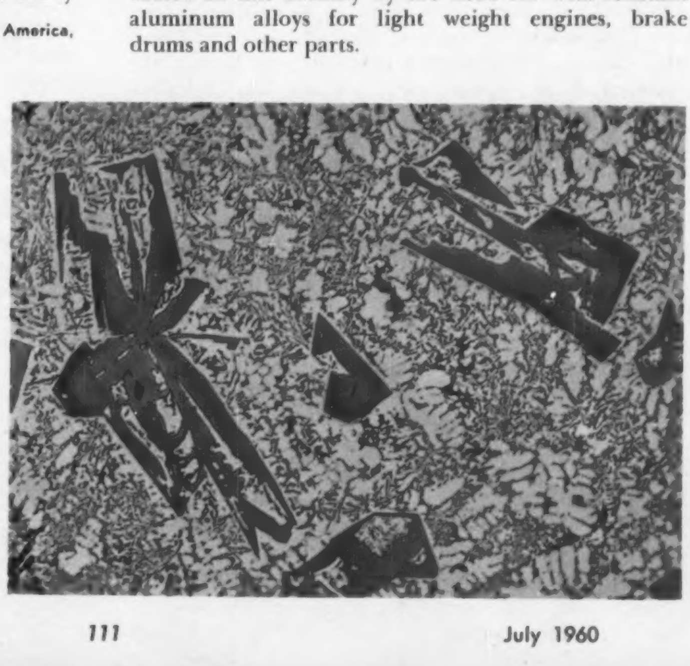


Fig. 1 — Microstructure of chill-cast hypereutectic Al-Si alloy 0.5 per cent HF etch. 100 ×.

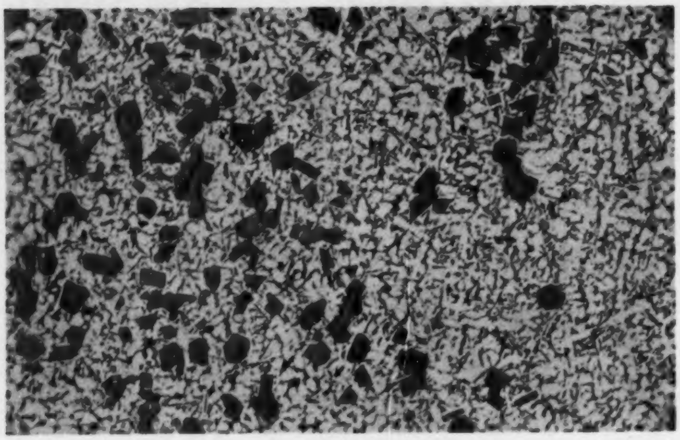


Fig. 2 — Same alloy as Fig. 1 after treatment with phosphorus 0.5 per cent HF etch. 100 ×.

Primary Silicon Refinement

Several sources of phosphorus have been used for refinement of primary silicon including red phosphorus, copper-phosphorus alloys, phosphorus pentachloride and different proprietary materials.[4,6,7] Satisfactory refinement generally is obtained with additions of about 0.01 to 0.05 per cent phosphorus. Retention of refinement is reasonably good, generally lasting for a 2 hr or longer holding period in the molten condition or through a pigging and remelting operation.[7]

Degree of retention appears to be dependent to some extent on the quantity of phosphorus introduced and the temperature at which the metal is held.[7] Phosphorus analyses have been somewhat variable, possibly because of segregation of this element, and the preferred range of phosphorus content in the alloy is not well defined.

The general opinion is that phosphorus combines with aluminum to form aluminum phosphide particles which are insoluble in aluminum at normal melting temperatures. These solid particles act as nuclei initiating the growth of many more silicon crystals than would be the case in the absence of favorable nuclei. Since sodium and calcium destroy the refining action of phosphorus, it is not possible to obtain simultaneous refinement of the primary silicon and modification of the eutectic silicon by means of sodium or calcium. As a matter of fact, sodium and calcium should be virtually excluded from the metal if optimum refinement with phosphorus is to be obtained.[2] However, fine eutectic silicon is provided in die castings by the rapid rate of solidification.

ALLOY DEVELOPMENT

As the silicon content of hypereutectic Al-Si alloys is increased, wear resistance is increased and the coefficient of thermal expansion is decreased, but castability, thermal conductivity, machinability and mechanical properties are adversely affected. The 19 per cent silicon in alloy X392 was selected to provide a desirable balance between these various properties and characteristics. The wear resistance of the 19 per cent silicon alloy appears to compare favorably with that of cast iron.[1,8] Small quantities of magnesium, copper and manganese were used in the alloy as hardening and strengthening agents.

Machinability tests indicated that the alloy should contain at least 0.5 per cent copper for satisfactory hardness and related machinability. Since high copper content has an adverse effect on the corrosion resistance of these alloys, this element was limited to a nominal 0.6 per cent in alloy X392. Also, efforts to improve feeding by substantial copper additions to the X392 composition actually resulted in an increased amount of shrinkage in castings.

The one per cent magnesium in alloy X392 was adopted to avoid formation of an excessive quantity of intermetallic Mg-Si compound, but to provide enough for improvement of strength and hardness. Manganese changes the form of Al-Fe-Si constituent so that it is less harmful to mechanical properties, and also contributes to good elevated temperature properties. Titanium is added for grain refinement in experimental sand and permanent mold casting but is not required in die casting.

Accordingly, the nominal composition selected for alloy X392 die castings is 19.0 per cent Si, 0.6 per cent Cu, 1.0 per cent Mg and 0.4 per cent Mn, with normal levels of impurities.

MELTING AND CASTING PROCEDURE

Metal pouring temperatures should be somewhat higher than those used for most aluminum casting alloys. Suggested pouring temperatures are normally in the range of 1350 to 1450 F for die castings, and from 1400 to 1500 F for permanent mold and sand castings.

Phosphorus refinement of the primary silicon is recommended for all castings. The beneficial effect of such refinement on machinability was revealed by a series of radioactive tool wear tests. The results expressed as per cent reduction in tool wear rate were:

Type of Casting	Refinement Effect on Tool Wear Rate, % Reduction
Die	36
Permanent Mold	54
Sand	69

The need for treatment with phosphorus is clear in the case of metal used in sand and permanent mold castings. Because of the rapid rate of solidification in die castings, there is little difference in the size of the primary silicon crystals in refined and unrefined metal. In spite of the slight structural change, however, refinement provided improvement in machinability of die castings.

Although hydrogen porosity is not a problem in alloy X392 die castings, thorough degassing should be employed for melts to be used in sand and permanent mold castings. As is the case with other alloys, fluxing with chlorine gas is most effective, although other degassing treatments may be used.

CASTING CHARACTERISTICS

Alloy X392 has excellent fluidity or die filling capacity and relatively good resistance to die soldering and hot cracking.[9] The feeding ability of the alloy is relatively poor in sand and permanent mold castings.[1,2,9] In the latter two types of castings, the alloy is subject to a concentrated or centerline type of shrinkage associated with solidification of a large quantity of eutectic material. Generous risering, and relatively steep temperature gradients between the first portions of the castings to solidify and the risers, are necessary to ensure sound sand and permanent mold castings.

MECHANICAL AND PHYSICAL PROPERTIES

Representative mechanical properties of alloy X392 obtained with die cast tensile specimens are listed in Table 1. This table also shows experimental values for sand and permanent mold specimens. The tempers for which properties are given are those most likely to be used in potential applications. The -T5 or -T7 temper provides substantial removal of growth and improved dimensional stability which may be important for applications involving operation at elevated temperatures. The -T7 aging treatment also reduces residual stresses resulting from quenching following solution heat treatment.

TABLE 1 — TYPICAL MECHANICAL PROPERTIES OF ALLOY X392[1]

Casting Process	Temper	Tensile Strength, psi	Bhn
Die, Typical	-F[2]	41,000	110
	-T5[3]	42,000	110
Sand, Experimental	-F[2]	22,000	75
	-T5[3]	26,000	85
	-T7[4]	32,000	110
Permanent Mold, Experimental	-F[2]	28,000	90
	-T5[3]	31,000	100
	-T7[4]	39,000	110

1. Elongations in all tempers approximately 0.5% for sand and permanent mold castings and 0.2% for die castings.
2. As-cast condition.
3. Artificially aged 8 hr at 400 F.
4. Solution heat treated 8-12 hr at 980 F, quenched in water at 212 F and artificially aged 8 hr at 400 F.

The hypereutectic Al-Si alloys have low elongations when compared to existing hypoeutectic alloys. This characteristic may result in contraction cracking in die casting or high stress concentration failure in service unless generous fillets and minimum variations in section thickness are used in casting design.

Refinement of the primary silicon with phosphorus provides some improvement in the tensile strength, but has little effect on elongation and hardness values. Refinement increased the tensile strength by 3000 to 5000 psi for sand castings and about 2000 psi for permanent mold castings.

Castings in the -T7 temper heated for 100 hr at 400 F had a Brinell hardness of 80 to 400 F and 105 after cooling to room temperature. This degree of retention of hardness may contribute to relatively good wear resistance during continued service at elevated temperatures.

The physical properties of alloy X392 are given in Table 2. As has already been mentioned, a high silicon content has a desirable effect both in lowering specific gravity and coefficient of thermal expansion. The latter characteristic is particularly important for parts such as pistons and engine cylinders where a small clearance is desirable.

TABLE 2 — PHYSICAL PROPERTIES OF ALLOY X392

Specific gravity		2.64
Weight/cu in.		0.095
Approximate melting range, F		1025-1245
Avg. coefficient of Thermal Expansion, in./in./F Range	-58-68	9.7×10^{-6}
	68-212	10.3×10^{-6}
	68-392	10.7×10^{-6}
	68-572	11.2×10^{-6}

Thermal Conductivity at 25 C, CGS Units	Temper	Casting Process	
	-F	Sand, PM, Die	0.22
	-T5	Sand	0.22
	-T5	PM, Die	0.23
	-T7	Sand	0.25
	-T7	PM	0.28

Alloy X392 is considered to have good resistance to corrosion.

APPLICATIONS

Alloy X392 die castings are being used for parts requiring resistance to wear and abrasion. The four commercial die castings in Fig. 3 are used in a belt driven automatic transmission for a motor scooter. Wear by the belts is considerably less than with 380 alloy. Automotive clutch friction rings are also being produced.

Other parts being tested include cylinder liners, cylinder blocks, pistons, brake drums, sheaves and pulleys.[1,8] In general, test results have been favorable from the standpoint of wear resistance, and demonstrate the advantage of the lighter weight and higher thermal conductivity of alloy X392 compared to cast iron.

Figure 4 shows a brake drum now undergoing development and testing. This part may be produced as a die or permanent mold casting, the choice depending upon design and quantities required. Test results show satisfactory machinability, brake surface

Fig. 3 — Four production die castings of alloy X392 for a belt-drive transmission.

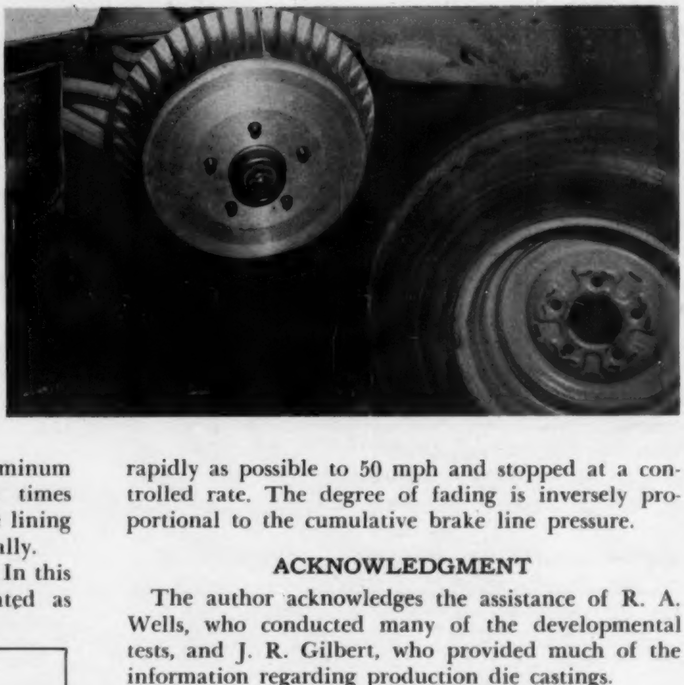


Fig. 4 — Hypereutectic Al-Si alloy brake drum undergoing development and testing.

condition and braking efficiency. The aluminum drums dissipate heat approximately three times faster than cast iron drums. As a result, brake lining temperatures and fading are reduced substantially.

The results of fade tests are shown in Fig. 5. In this test, the automobile was repeatedly accelerated as rapidly as possible to 50 mph and stopped at a controlled rate. The degree of fading is inversely proportional to the cumulative brake line pressure.

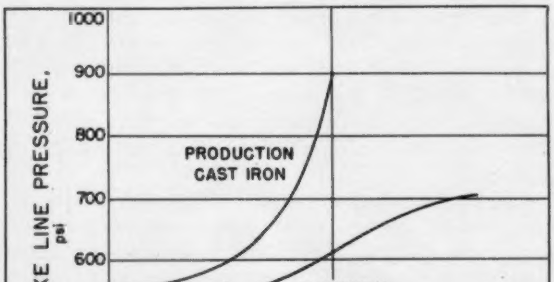


Fig. 5 — Fade tests of hypereutectic Al-Si alloy and production cast iron brake drums.

ACKNOWLEDGMENT

The author acknowledges the assistance of R. A. Wells, who conducted many of the developmental tests, and J. R. Gilbert, who provided much of the information regarding production die castings.

REFERENCES

1. R. M. Smith, "Hypereutectic Aluminum-Silicon Alloys," *S.A.E. Journal, 48* (Sept. 1958).
2. R. Kissling and O. Tichy, "A Hypereutectic Aluminum-Silicon Alloy," AFS TRANSACTIONS, *vol. 67*, p. 347 (1959).
3. C. Bücken, "Karl Schmidt G.m.b.H.," *Metal Industry*, p. 280 (Oct. 5, 1956).
4. H. Kessler, "Aluminum Piston Alloys in Germany," *Light Metals*, p. 85 (March 1958).
5. U.S. Patent 1940922 (Dec. 1933).
6. H. Kessler and H. Winterstein, "Significance of Particle Size of a Grain Refining Agent," *Z. Metallkde, 47, 97,* (1956); *Light Metals*, p. 294 (Sept. 1956).
7. J. Koritta and A. Franek, "Modification of Hypereutectic Al-Si Alloys with Phosphorus Pentachloride," *Hutnicke Listy, XIII*, no. 12, p. 1081 (1958).
8. J. M. Smith and R. M. Smith, "Aluminum Engines — Design for Modern Fabrication," *S.A.E. Transactions, vol. 67*, p. 295 (1959).
9. R. Kummerle, "Casting Properties of the Aluminum-Silicon System," *Metall, vol. 11*, no. 10, p. 848 (Oct. 1957).

F. E.'s FULLY AUTOMATIC SHELL CORE BLOWER

POWER CONSUMPTION: 20"x16" heater plate, 16½ KW — 20"x24" plate, 24 KW.

AIR PRESSURE: 80-100 p.s.i. Regulator, filter, lubricator supplied.

HEATER PLATES: Plug-in receptacle for easy change-over. Thermostat-control. Heavy-duty, cast-in elements.

HYDRAULIC CYLINDERS: Have case-hardened, chrome-plated rods.

CONTROL PANEL: Standard equipment — investment, cure, rocking timers.

SAND BOX: Adjustable to suit core box parting line. Can be supplied with automatic refill unit.

OVER-ALL BLOWER DIMENSIONS: Length 80", width 52", height 50".

F. E.'s new, streamlined Shell Core Blower uses two standard size, interchangeable heater plates — 20"x16" for core box sizes up to 20"x17"x14", and 20"x24" for boxes to 20"x25"x14".

All movements hydraulically controlled. Hydraulic unit and electric control panel self-contained, placed for convenience. Cores are ejected by means of a "flip-plate" assembly, which virtually "hands" cores to the operator. At no time does the operator have his hands between the heater plates.

F. E.'s Shell Core Blower is fast, efficient and very easy to operate. Turns out perfect shell cores — no core breakage, no core box wear. Quickly changed from fully-automatic to single cycle control. Easily set up and economical to operate.

Additional information and prices on request.

F. E. NORTH AMERICA, LTD.

47 ADVANCE ROAD, TORONTO 18, ONTARIO, CANADA

TELEPHONE: BELMONT 3-3227 • **TELEGRAMS:** EQUIPMENT, TORONTO

MOLDING MACHINES • SANDRAMMERS • SHELL MOLD AND CORE MACHINES • COMPLETE SAND HANDLING SYSTEMS

Circle No. 134, Page 139

Cooperation Key to Providing Auburn with Latest in Foundry Production Equipment

Cooperation between school officials, industry and past chairmen of the AFS Birmingham Chapter has provided Auburn University (formerly the Alabama Polytechnic Institute), Auburn, Ala., with one of the most modern foundry laboratories in the south.

While the laboratory process in metallurgical foundry work has been offered for some time at Auburn, the program suffered from use of obsolete equipment.

Auburn's dean of engineering, Fred H. Pumphrey, gives Dan T. Jones, head of industrial laboratories, credit for visualizing a completely new foundry. The problem facing the school was the difference between what was needed in new equipment and what could be afforded with its state appropriation.

With Pumphrey's approval, Jones began telling the story of the university's foundry needs. Harry Burns, factory manager, Stockham Valves & Fittings, Inc., Birmingham, Ala., became the spearhead of a movement to modernize the school's facilities.

The project started to gather momentum in a Nov., 1958 planning session involving Burns, former AFS President and Birmingham Chapter Chairman L. H. Durdin, Dixie Bronze Co., Birmingham, former Birmingham Chairman M. D. Neptune, James B. Clow & Sons, and school officials.

Manufacturers and suppliers were informed of the proposed plans and rallied to the cause by generously contributing all the needs of a modern foundry laboratory. Among the donors were:

Shalco Div., National Acme Co., Cleveland; Centrifugal Casting Machine Co., Tulsa,Okla.; Whiting Corp., Harvey, Ill.; Standard Conveyor Co., St. Paul, Minn.; Cleveland Tramrail Birmingham Co., Birmingham; Pangborn Corp., Hagerstown, Md.; Beardsley & Piper Div., Pettibone Mulliken Corp., Chicago; National Engineering Co., Chicago; Refractories Div., H. K. Porter Co.; Bessemer, Ala.; and Osborn & Co. Truck Lines, Birmingham.

The basic engineering for the facility was contributed by Stockham Valves & Fittings, Inc.

"The re-equipping of the foundry is going to enable Auburn to provide better assistance to industry," said the dean. "Young engineers, taking the foundry technology course, will as graduates, be better able to understand many engineering problems that they will face in industry. And this is all because of new techniques and methods that now can be taught by use of the new equipment. The facility is helping Auburn to accentuate the general tone of excellence it is acquiring in all its areas of engineering instruction and research."

"While the laboratory process in metallurgical foundry work is a longstanding practice at Auburn, the new, modern machinery and equipment will improve, expedite and modernize it," explained Jones. "Student instruction has been furnished by the industrial laboratories for many years in the sciences of patternmaking, foundry, machining, metal fabricating, and welding as the fundamental modes of manufacture."

Foundry technology at Auburn University includes lectures, demonstrations, and actual use of the equipment. Student is blowing core on donated equipment.

Dr. William Lane, head of the industrial management department; Dr. Luther Haynes and Dan T. Jones, industrial laboratories; Harry Burns, factory manager, Stockham Valves & Fittings, Inc., Birmingham, Ala.; and Dean Fred Pumphrey look over the newly equipped foundry laboratory at Auburn University.

AFS-TRAINING & RESEARCH INSTITUTE

1960 EDUCATIONAL COURSES

AUG.—SEPT.

Subject and Description	*Dates*	*Where Given*	*Course Fee*
Blue Print Reading, Estimating	**Aug. 17-19**	**Chicago**	**$60**
Core Practices	**Aug. 29-Sept 2**	**Chicago**	**$90**
Foundry Refractories	**Sept. 12-14**	**Chicago**	**$60**
Economical Purchasing of Foundry Materials	**Sept. 26-28**	**Chicago**	**$60**
Welding and Brazing of Castings (Originally scheduled Aug. 17-19)	**Postponed**	**Chicago**	**$60**

Blue Print Reading, Estimating — Aug. 17-19 — Chicago — $60

Basic fundamentals and principles necessary when considering new jobs. Job analysis techniques are presented in logical step-by-step procedure . . . including the initial reading of blueprints to production planning. Practical methods of estimating new jobs are studied, emphasizing "danger points" which can increase production costs. This course covers information which is vitally important for economically successful foundry operations. Key personnel involved in these responsibilities can learn new techniques. **Course No. 8**

Core Practices — Aug. 29-Sept 2 — Chicago — $90

Concentrated core instruction for foremen, sales engineers, supervisors, technicians, engineers, and management. All aspects of materials, mixing, sand testing, economical application, advantages and limitations of new processes and materials are studied. Casting losses attributed to cores are analyzed for solutions. Case problems are welcomed for class discussion. **Course No. 10.**

Foundry Refractories — Sept. 12-14 — Chicago — $60

Intensive specialized instructive course, providing informative, up-to-date- technology on foundry refractories. Emphasis on types, selection, use, maintenance and economy in foundry practices. Course provides broad understanding of expendable foundry materials and how the intelligent use can reduce operating costs. Course designed for supervisors, foremen, technicians, engineers and management. **Course No. 11.**

Economical Purchasing of Foundry Materials — Sept. 26-28 — Chicago — $60

Course gives detailed instruction on intelligent buying of scrap, refractories, sand, alloys, binders, core oil, additives, etc. Includes up-to-date information on all aspects of foundry materials purchasing. Valuable to supervisors, engineers, purchasing agents, foremen, and management. **Course No. 12.**

Welding and Brazing of Castings (Originally scheduled Aug. 17-19) — Postponed — Chicago — $60

Practical analysis of "when" and "how" to repair ferrous and non-ferrous castings. Equipment, new methods, filler rod alloys, new techniques and applications. Welding and brazing technology as it relates to castings, and the fabrication of component castings with wrought materials. Metallurgy, mechanical properties and heat treatment of parent and weld metal are also discussed. **Course No. 9**

REGISTRATION: Make reservations for all 1960 AFS-T&RI training courses by course numbers and dates given. Registrations accepted in order as received at AFS Headquarters, Golf & Wolf Roads, Des Plaines, Ill.

T&RI Expands Courses to Meet Industry's Needs

How the AFS-Training & Research Institute courses are constantly expanded to meet the needs of the industry is illustrated in the four sessions to be conducted in August and September.

Core Practices has been presented previously. However, the other three, *Blue Print Reading and Estimating, Foundry Refractories* and *Economical Purchasing of Foundry Materials,* will be given for the first time.

Each represents the latest information available with authorities in the field donating their time as instructors. All courses will be given in Chicago. A summary of the material is found on this page.

Cutting of foundry costs through an effective maintenance program was outlined in Indianapolis June 1-3 in a course co-sponsored by the Central Indiana Chapter in cooperation with the AFS Training & Research Institute.

Included in the course were how to set up and operate the program, equipment maintenance problems, air and safety factors, materials handling and physical plant considerations, and recommendations for molding and core machines.

Instructors were: K. M. Smith, Caterpillar Tractor Co., Peoria, Ill.; Richard Allchin, Rotor Tool Co., Cleveland; Warren Rhoades, Cooper-Besemer Corp., Dallas, Texas; R. W. Donnelly, H. G. Greiner, and W. R. Jaeschke, Whiting Corp., Harvey, Ill.; William D. Lee, General Electric Co., Schenectady, N. Y.; H. J. Weber, AFS Director of Safety, Hygiene & Air Pollution Control; S. A. Simonson, Chicago Hardware Co., North Chicago, Ill.; George Koren, Beardsley & Piper Div., Pettibone-Mulliken Corp., Chicago; R. E. Betterley, T&RI Training Supervisor.

Groups Outline Investigations

Committees of the technical divisions at recent meetings have reported the status of their investigations. These include:

Thermal Cracking

A compiling of problems, conditions and solutions encountered in shell and core thermal cracking is being undertaken by the Sand Division Shell Mold and Core Committee.

A composite questionnaire is being designed to accumulate data on operating conditions and solutions. Completed questionnaires will be sent to AFS Headquarters and a committee will edit them for publication and a possible presentation of a paper at the 1961 Convention.

Assignments were made to three committees for the preparation of a tentative standard test for shell or core cure rate and pickup thickness. Also under study will be further investigation of the melt point (stick point) test. The committees will accumulate data for publication and consideration as advanced research work.

Trapping Non-Metallics

Further investigation of gating as a means of trapping non-metallics will be included in further work of the AFS Steel Division Research Committee.

The investigation will include additional laboratory experiments using a test casting in the form of a plate approximately 1/2x10x14 in. Following these tests, and having established proper geometry for the gating system, cooperating foundries will be requested to make test castings using the same gating systems.

Further investigation will be made of the refractory-metal reactions as a means to eliminate snotters from this source, utilizing varying metal compositions, deoxidizers and refractories.

Ultra Violet Inspection

Ultra violet light inspection interpretation has been selected as the most desirable subject for development by the Malleable Division at the 1961 Castings Congress to be held in San Francisco.

A. R. Lindgren, Magnaflux Corp., Chicago, has agreed to prepare the initial presentation which will be reviewed by committee members. In addition, members have been requested to provide problem castings. The castings and an explanation of the problem will be presented.

Four Foundry Educational Foundation scholarships were given to University of Illinois students at the annual Industrial Night, April 27. Presentation of awards was made by Fred Strom, left, Griffin Wheel Co.

Winners shown are R. W. Kotrba, C. H. Jones and E. H. Ernst. G. R. Boyd was not present. Faculty advisor of the AFS University of Illinois Student Chapter, Prof. J. W. Leach, is on right.

Schedule Technical Sessions for 1961 Congress in San Francisco

Tentative scheduling of sessions has been made for the 65th Castings Congress to be held May 8-12 in San Francisco. Technical meetings will be presented in the Civic Auditorium while the concurrent Exposition will be held in Brooks Exhibit Hall.

Sand sessions will be held on each of the five days. Other divisions and general interest committees and their tentative days are:

Light Metals—Monday, Tuesday.

Brass & Bronze—Monday, Tuesday.

Malleable—Monday, Tuesday.

Pattern—Monday, Tuesday.

Gray Iron—Tuesday, Wednesday, Thursday.

Die Casting & Permanent Mold—Wednesday, Thursday.

Steel—Wednesday, Thursday.

Ductile Iron—Thursday, Friday.

Safety, Hygiene & Air Pollution—Tuesday.

Education—Tuesday.

Industrial Engineering & Cost—Tuesday, Wednesday.

Plant & Plant Equipment—Wednesday.

Fundamental Papers—Thursday.

Heat Transfer—Friday.

Six shop courses will be conducted; two each by the Malleable and Gray Iron Divisions and one each by Sand and Ductile Divisions.

Illinois Student Chapter Conducts Program

Members of four University of Illinois student chapters of technical societies attended the annual Industrial Night on April 27. The AFS Student Chapter planned the meeting and served as host. Chapter Chairman Max Adamski, presided.

Student members of the American Society of Mechanical Engineers, American Society of Industrial Engineers and Society of Automotive Engineers also attended.

Four Foundry Educational Foundation scholarships were awarded to sophomores in mechanical engineering. Recipients were: George R. Boyd, Urbana, Ill.; Charlton H. Jones, Flossmoor, Ill.; Charles H. Ernst, Gibson City, Ill.; and Roymond W. Kotrba, Chicago. Presentations were made by Fred Strom, Griffin Wheel Co., Chicago.

A Wheelabrator graduate fellowship was awarded to Joseph R. Strode by Charles W. Vokac, Hydro-Arc Furnace Div., Whiting Corp.

Kenneth A. Stonex, General Motors Proving Grounds, Milford, Mich., addressed students on safety research at the proving grounds. AFS Education Director R. E. Betterley, spoke on the spirit of cooperation exhibited by the student groups.

Tennessee Sponsors Course in Melting

A course on *Cupola Melting of Iron,* co-sponsored by the AFS Tennessee Chapter and the AFS Training & Research Institute, will be given July 25-29 at the Patten Hotel, Chattanooga, Tenn. The course provides principles of cupola operation with emphasis on cost reduction. The course fee is $90.

CHAPTER NEWS

CENTRAL INDIANA—Attending the annual past chairman's dinner were: Bill Faust, Bill Fitzsimmons, Fred Kurtz, Harold Lurie, Pres Lentz, Dick Bancroft and Frank Swain—by William R. Patrick

NORTHWESTERN PENNSYLVANIA—Symposium on casting defects was held on consecutive nights during April. Panelists were Ray Cochran, R. Lavin & Sons; D. L. LaVelle, Federated Metals Div., American Smelting & Refining Co.; David Matter, Ohio Ferro-Alloys Corp.
Also Clyde Sanders, American Colloid Co.; Ralph White International Nickel Co. Not shown moderator W. J. Wilmot, Urick Foundry Co.—by Walter Napp

SAGINAW VALLEY—Student activity night was held during April. Shown are: Chapter Chairman Ormond Requadt, Dr. H. Baker, administrative assistant, General Motors Institute; Edward Walsh, executive director, Foundry Educational Foundation; Chapter Vice-Chairman George R. Frye; Major Albert Sobey, president emeritus, General Motors Institute.—by John R. Fraker

EASTERN CANADA—Clyde Sanders, American Colloid Co., Skokie, Ill., on left, was the speaker at the April meeting. Others are Chapter Chairman A. H. Lewis, Crestweld Mfg., Ltd., Lachine, Que.; W. D. Dunn, Oberdofer Foundries, Inc., Syracuse, N.Y., then an AFS National Director; and National Director A. J. Moore, Canadian Bronze, Ltd., Montreal, Que.

SOUTHERN CALIFORNIA—Apprentice winners in the chapter's patternmaking contest were: Stanley Bakula, 1st place, student; Timothy R. Osborn, 2nd place, student; Duane Garn, 2nd place, commercial; P. Peterson, 1st place, commercial; C. A. Ayers, 1st place, metal pattern competition.—by K. F. Sheckler

Northeastern Ohio Chapter

Shell Core, Mold Symposium

A four-man panel at the April meeting discussed shell cores and molds. Robert J. Mulligan, Archer-Daniels-Midland Co., served as moderator. Members were Allan G. Hill, Durez Plastics Div., Hooker Chemical Corp.; Marvin Wolf, Standard Brass Foundry Co.; Charles J. Jelinek, Cleveland Foundry, Ford Motor Co.; Lauren Hexamer, SPO, Inc.

Hill stated that shell molding fills a niche between dry and green sand and investment casting. Some draft is required in vertical sections of patterns, ranging from ¼ to ½ degree. Sand particles should be small, but more resin is required as size is reduced. A good compromise is to use the coarsest sand which will produce the tolerances and finish required. Shell can produce excellent finish and tolerances, but the nature of the process is such that a good mold can produce bad castings because of certain factors such as changes in the mold under heat, lack of chilling action in the mold and slow solidification of metal.

Wolf noted that shell core and shell molding hasn't begun to tap its full potential. Advantages include the use of less sand, space and equipment; easy automation; reduction of need for skilled labor; and elimination of many usual defects.

Hexamer pointed out that shell core boxes require efficient thermal conductivity and that mating surfaces must be flat to insure a good seal. Venting permits displacement of air in the cavity and permits sand to be carried in by air so that a good, solid core is achieved. The vent-blowhole ratio should be 4 to 1. A good practice is to start with no vents, then place them where needed as indicated by the cores produced. Slotted and screen vents are difficult to clean, but milled slots do a good job when properly placed. An effective technique uses a milled slot along the parting line on the face of the box.

Jelinek discussed the development of coated sands which can be either hot or cold coated. Both methods require a skilled muller operator and alert supervision. The resultant sand must be uniform and fine, without residual solvents which restrict flow. Thorough aeration is necessary to remove the residual solvents. The cool or cold coating methods uses liquid resin, and the hot coating ordinarily employs a dry powder, although liquid can be used. Pneumatic conveying of coated sand as yet has not been as successful as the use of cyclone collectors, said speaker JeLinek.—by Jack C. Miske

From cradle to dry hearth, Hevi-Duty provides the right melting furnace for your job

Yes, Hevi-Duty can provide the furnace you need. It's probably a standard unit, for at Hevi-Duty you have a wide choice of sizes and types. If not, though, you've *still* come to the right place.

Hevi-Duty is a company of engineers, trained to solve heat processing problems and to design special equipment to meet your requirements. When you ask to see a Hevi-Duty representative, a man with application engineering experience will call on you. You can depend on him to recommend the most efficient system as well as the best furnace or oven for you.

So why not call on him. He will be glad to stop in, and you could be very glad he did.

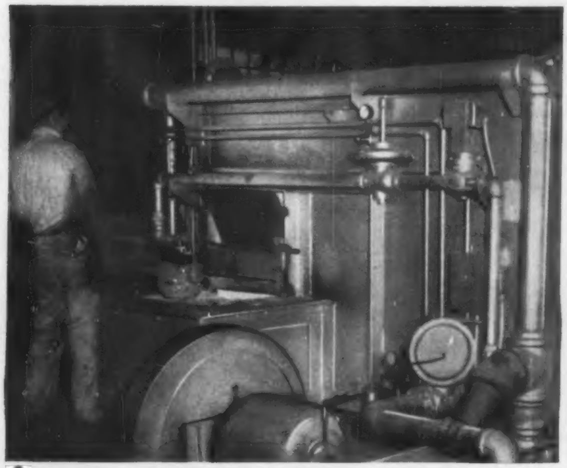
HEVI-DUTY

Electric and Fuel-Fired Industrial Furnaces and Ovens

B P C

A Division of Basic Products Corporation

Hevi-Duty Electric Company, Milwaukee 1, Wis.



This double chamber dry hearth furnace was tailored to the specific needs of Eastern Castings Corporation, Newburgh, N. Y. It is used for permanent mold aluminum casting at temperatures up to 1550°F. For this high-temperature application, structural steel was moved to the outside of the shell and insulation was increased to accommodate the higher temperature. The user reports continuous, high production at tremendous savings on maintenance. ***For more information, please send for Bulletin 594.***

This dry hearth melting and holding furnace is used for many different aluminum alloys at Manufacturing Research, International Harvester Company. It is gas fired, has a melting rate of 750 pounds per hour and a holding capacity of 1,000 pounds. The pit beneath the pouring spout enables the company to pour castings as large as the holding capacity of the furnace. ***Request Bulletin 594.***

Dollin Corporation, Irvington, N. J., has purchased this cradle tilting reverberatory furnace for breaking down and holding aluminum. It handles a larger volume of metal at lower cost than the furnaces it has replaced. There is also a better balance of heat, resulting in cleaner metal. Working conditions are cooler near the unit, and its design provides for easy drossing. ***Please write for Bulletin 691.***

Circle No. 143, Page 139

ST. LOUIS—Panelists at the May meeting who discussed college education and the foundry industry. Left to right: Ray Miller, National Bearing Div., American Brake Shoe Co.; Dr. Dan Eppelsheimer, Missouri School of Mines; moderator John Rendall, Miller & Co.; W. Illig, Banner Iron Works; and J. H. Thompson, Bodine Pattern & Foundry Co.

SOUTHERN CALIFORNIA—More than 125 members attended the May meeting to hear Lt.-Col. William O'Brien, Air Force Ballistic Missile Division speak on "Man in Space." Shown with O'Brien is Frank Warga, AiResearch Mfg. Co., former chapter chairman. —by K. F. Sheckler

NORTHEASTERN OHIO—Chapter apprentice winners shown with Dudley C. Courtright, who retired June 24 after having been principal of the Max S. Hayes Trade School since 1936.

Winners are Mack Collins, Robert Holt, G. Scheibah, Ronney Sekala, Douglas Maier, Bradley Smith, John Sabanos, Ron Koehule, and Harry Wozciechowski.—by Harold Wheeler

TENNESSEE—Chapter Chairman C. E. Seman, Crane Co., presiding at annual ladies night attended by 270 foundrymen and their wives. —By James L. Duggan

SAGINAW VALLEY—Dr. Orlo L. Crissey, General Motors Institute, Flint, Mich., explained at the May meeting how to make human relations effective in the foundry. Shown are Technical Chairman Elmer Braun, Central Foundry Div., GMC; speaker Crissey and Chapter Chairman Ormond Requadt, Dow Chemical Co.—by John R. Fraker

BIRMINGHAM—Panelists at the May meeting and their subjects were: Lloyd L. Stone, Stockham Valves & Fittings, Inc., Birmingham, "High Pressure Molding;" Ray Hathhorn, Rudisill Foundry Co., Anniston, Ala. "A New Method for Shell Molding; and John Warner, Tyler Pipe & Foundry Co., Tyler, Texas, "Permanent Mold Casting of Gray Iron."—by John Jetton

CHICAGO—Cast pouring statue awarded each year by the chapter to its retiring chairman. The award this year was given to John Mulholland, Pettibone Mulliken Corp.

Metropolitan Chapter

Green Sand Casting Process

Foundries should choose sands geared to the average casting thickness, using synthetic or natural sands depending upon facilities available, Victor Rowell, Archer-Daniels-Midland Co., Cleveland, stated at the April meeting.

He cited moisture as the greatest evil of molding sand variables with high permeable sands being the safest from the standpoint of gas troubles. High clay controlled sands with low moisture are the most thermally stable and provide the best finish. The dry strength to green strength ratio should be approximately 5 to 1; the clay percentage to moisture ratio, 3 to 1.

George Pettinos, Pettinos Sand Co., spoke on sand segregation as influenced by hopper design. He accompanied his talk with a film illustrating how coarser and heavier sand grains tend to flow before smaller aggregates.

The meeting was attended by 150 members and guests with George Watson, American Brake Shoe Co., acting as technical chairman.—by C. H. Fetzer

CHICAGO—Two visitors from Edinburgh, Scotland, Danny Brown, Bonnington Castings Co., and Kenneth Evans, Balbardiee, Ltd., meet with Ted Haines, Woodruff & Edwards, Elgin, Ill., on left, at May chapter meeting.—by George DiSylvestro.

CHICAGO—Jack Irish, Texas Foundries, Inc., Lufkin, Texas, prepares to tackle his talk on "Short Cuts—Texas Way" at the May meeting.—by George DiSylvestro

BRITISH COLUMBIA—Herb Heaton, Mainland Foundry Co., Vancouver, British Columbia, and chairman of the 1960 Annual Northwest Regional Conference to be held in Vancouver, Oct. 21-22, reviews plans with vice-chairman Charles C. Smith, General Metals Co., Vancouver.—by H. Bromley

DETROIT—Ductile iron, its current status and possibilities were discussed at the May meeting by W. H. Dawson, International Nickel Co. Shown are technical chairman H. N. Bogart, Ford Motor Co., and speaker Dawson.

OREGON—Project leaders from the Bureau of Mines brought samples of cast reactive metals to the April meeting. Left to right are: Floyd Wood, Philip Clites, and Eugene Calvert.—by Bill Walkins

DETROIT—Son and father at chapter's May meeting: W. H. Dawson, International Nickel Co. and George I. Dawson, Jones-Mundle Co.

Quad City Chapter

Celebrates 40th Anniversary

Twenty-five years as an AFS Chapter and 40 years existence as a foundrymen's group were acknowledged at the March meeting.

Organized as the Quad City Foundrymen's Association in 1920 and becoming an AFS Chapter in 1935, the chapter now has more than 200 members. A. E. Hageboeck represented the past chairmen at the meeting and outlined the history of the chapter.

Past chairmen honored were: A. E. Hageboeck, Hy Bornstein, John Diedrick, A. H. Putnam, T. J. Frank, Bob Eickman, C. H. Burgston, A. D. Matheson, W. E. Jones, R. E. Wilke, C. R. Von Luhrte, C. S. Humphrey, R. H. Swartz, E. P. Closen, H. A. Rasmussen, W. C. Bell, Boyd Hayes, Eric Welander, William Ellison, C. C. Fye, Lyle Brogley, M. H. Horton and E. F. Petersen. Deceased past chairmen honored were: C. Bancroft, J. Ploehn, Fred Kirby and M. H. Liedke.

Oregon Chapter

Reactive Metal Discussion

Melting and casting of reactive metals was the subject of a panel discussion at the April meeting. Three project leaders from the U.S. Bureau of Mines, Albany, Oregon, headed the discussion. They were Floyd Wood, Eugene D. Calvert, and Philip G. Clites.

The discussion evolved under four general headings; why we arc melt, how the process came about, type of facilities used in industrial plants, and some of the problems involved. Laboratory and research work being done at the Bureau of Mines in the melting and processing of reactive metals was described.

Reactive metals are so chemically active that they react with practically all other elements. They must be protected at all times, and are melted in a vacuum by the consumable electrode arc method. The degree of vacuum varies with the volatility of material being melted and the type of equipment used. Crucibles in general are water cooled copper. Inert gases are used in cases where great vacuum is not desired. Some metals are also melted using non-consumable electrodes.

The metal is melted and poured inside the furnaces. Molds generally are of machined graphite, although research is under way to develop expendable molding materials.

Many of the reactive metals are now being melted commercially. Ingots up to 16 inches diameter are being produced in titanium and zirconium. Columbium is now being processed from oxide to ingot. The U.S. Government is the sole user of columbium and purchases all of the metal.

Problems in the melting and casting of reactive metals include the explosion hazard, mold materials, and cost reduction. All explosions to date have occurred in the melting of titanium.

A color film showed arc melting electrodes in action in a vacuum furnace.—by Bill Walkins

PITTSBURGH — Attending April meeting are A. S. Pander, Homestead Valve Co.; K. R. Braddock, Frederic B. Stevens Co.; T. O. Fritz, McConway & Torley Co.—by Walter Napp

CENTRAL ILLINOIS—Mechanization in small foundries was explained at the May meeting by Jeff Westover Westover Corp., Milwaukee.

Flanking Westover are technical chairmtn W. E. Schulze, Jr., Caterpillar Tractor Co., and Chapter Chairman John Kauzlerich, Peoria Malleable Castings Co.—by Charles Bavis.

CENTRAL ILLINOIS—New officers: Director I. J. Ladd; Vice-chairman H. L. Marlatt; Chairman C. J. Turner; Director D. P. Schmitt. Director J. W. Wagner, Jr., is not shown.—by Charles Bevis

SAGINAW VALLEY—Fred Hodgson, Foundry Div., Eaton Mfg. Co., and Dick Robbins, Albion Malleable Iron Co., April told how F. E. F. scholarships had assisted them in their education.—by John R. Fraker

NEW ENGLAND—What research can mean to the foundry industry was explained at the April meeting by M. C. Flemings, Massachusetts Institute of Technology, right. Others are Ahti A. Erkkinen, Chapter Chairman, and John M. McCloskey of the M.I.T. Student Chapter. The meeting was held at the M.I.T. experimental foundry.—by F. S. Holway

SAGINAW VALLEY—Ormond Requadt, left, Saginaw Valley Chapter Chairman, presents award of appreciation to former chairman Arthur H. Karpicke at April meeting.

PITTSBURGH—Dr. R. W. Zillman, Pittsburgh Steel Foundry Co., left, discussion leader at the April meeting with speaker E. E. Woodliff, Foundry Sand Service Engineering Co.—by Walter Napp

CENTRAL NEW YORK—Curtis M. Fletcher, a past chairman and an active foundryman for 48 years receives camera from former chapter chairman Don Merwin.

John Kura, Battelle Memorial Institute, Columbus, Ohio, spoke on the principles of gating, and showed a Battelle film outlining their application.—by L. Balduzzi

ONTARIO—More than 350 members and wives attended the annual Ladies Night in April. Lindsay Cooper, Canada Iron Foundry Ltd., served as entertainment chairman.

In photo, Mrs. Ted Tafel, receives bouquet of roses from Cooper.—by M. E. Hollingshead and Vincent H. Furlong

OREGON—Principles of gating, demonstrated by slides and water anology models were presented at the May meeting. William A. Meyer, Electric Steel Foundry Co., was the speaker, with John Kunis, also of Electric Steel Foundry Co., assisting in the demonstration.—by Bill Walkins

SOUTHERN CALIFORNIA—James W. Smith, Oregon Metallurgical Corp., Albany, Ore., centered. dicussed vacuum casting of reactive metals at the April meeting. On left is technical chairman C. F. Weisgerber, Alloy Steel & Metals Co. and chapter chairman E. G. Gaskell, Ace Foundry, Ltd.— by K. F. Sheckler

Circle No. 144, Page 139

St. Louis Chapter

Colleges and Industry

Eighty-six foundrymen and students from the Missouri School of Mines, Rolla, Mo., in May heard a panel discussion on "Are Colleges Doing a Job for the Metalcastings Industry." Representing education were Dr. D. Eppelsheimer and R. Wolf. Representing industry were W. Illig, Banner Iron Works, St. Louis and two recent graduates from the Missouri School of Mines, Ray Miller, American Brake Shoe Co., National Bearing Div., and Jack Thompson, Bodine Pattern & Foundry Co., St. Louis. John Rendall, Miller & Co., acted as moderator.

From the educational viewpoint it was pointed out that universities could not aim engineering students at any one industry but must give the basic background enabling students to enter many different fields. Colleges believe that they have made progress and are aware of the needs of the foundry industry and have tried to meet these demands as far as practical.

Illig reminded students that one item that could not be taught in schools was experience. He urged students to ask questions to find why certain methods were used and told them not to look down on men without college educations but who possessed years of practical experience. It was his contention that smaller shops offer more to young students by providing more diversified experience.

Miller stated that universities must provide basic tools and the man himself must develop further. He said that industry must give the help needed for this through training courses and technical aids.

It was Thompson's opinion that colleges should give more humanity courses to engineering students to enable them to express themselves. He stated that industry should prepare the way for new engineers by stressing the need among their employees and that engineers be given responsibility as soon as possible and be faced with challenging problems rather than routine jobs. He should also be urged to continue his education through various means.—by W. E. Fecht

Northwestern Pennsylavania

Castings Defect Panel

A two-evening symposium in April on casting defects attracted 200 foundrymen and guests from the Pittsburgh, northwestern New York, northeastern Ohio and Canton, Ohio.

Each was presented with the AFS CASTING DEFECTS HANDBOOK. Visits were also made to the General Electric Corp. plant and Erie Forge & Steel Corp.

Various defects in iron, steel, ductile iron, aluminum and brass and bronze castings were discussed. Each defect was projected on a screen and pertinent information given. The panel identified the defect, and advanced possible causes and solutions. A discussion from the floor followed each case.

Panelists were: Ray Cochran, R. Lavin & Sons, Inc., Chicago; D. L. LaVelle, Federated Metals Div., American Smelting & Refining Co., South Plainfield, N.J.; David Matter, Ohio Ferro Alloys Corp., Canton, Ohio; C. A. Sanders, American Colloid Co., Skokie, Ill.; and Ralph White, International Nickel Co., New York.

W. J. Wilmot, Urick Foundry Co., Erie, Pa., served as moderator.

The symposium was sponsored by the chapter's education committee and held April 11 and 12 at Memorial Junior High School, Erie, Pa.

Plant visitations were also made to the General Electric Corp. facilities and Erie Forge & Steel Corp.—by Walter Napp

Washington Chapter

Makes Tour of Factory

Chapter members visited the Renton plant of Boeing Airplane Co. at the May meeting. Included was a dinner at the company's cafeteria, a tour of the production facilities, and an inspection of commercial planes.—by Hubert L. Rushfeldt

Washington Chapter

Vacuum Casting Techniques

The basic problems in casting metals having a high affinity for oxygen, nitrogen and hydrogen are in the melting and casting mediums, Said James W. Smith, Oregon Metallurgical Corp., Albany, Ore.

These metals, explained Smith at the April meeting, must be melted in a vacuum. Added to this is the fact that titanium and zirconium will react with all refractories and to some degree with carbon.

The electric arc melting furnace is inside the vacuum pot and capable of melting up to 400 pounds of titanium. The vacuum pot is of sufficient size to cast single molds, several molds on a turntable or continuous cast pipe centrifugally. The utilize scrap, the material is welded together and used as an electrode. Corrosion resistance and strength-to-weight ratio are the prime reason for the casting of titanium and zirconium castings. Hubert L. Rushfeldt

Wisconsin Chapter

Dutch Testing Techniques

An outline of Dutch foundry testing techniques was presented at the May meeting by Clyde A. Sanders, American Colloid Co., Skokie, Ill. A film was shown illustrating some new heat shock, hot strength testing devices for foundry molding sands and coatings.

By creating a semisphere, approximately three inches in diameter and then subjecting this specimen to an elevated temperature, the reaction between the mold surface and the high heat produced a visual end result of the surface area.

Some sands cracked, some coatings spalled, as volume changes occurred surface phenomena was recorded. Predictions could then be made as to what occurred when high temperatures were created against mold surfaces. It was found that certain carbon additives were beneficial to specific sand mixtures and predictions could be made ahead of casting procedures.

Water dip tests were also shown and sand specimens that spalled easily in water generally denoted mixtures that would also spall when subject to hot metal.

Ontario Chapter

European Foundry Practices

European foundry practices were discussed at the May meeting by C. A. Sanders, American Colloid Co., Skokie, Ill. He emphasized that European foundries were considerably ahead in technical know-how and that their casting finish is near perfection.—by Vincent H. Furlong

---

AFS Chapter Meetings

JULY

Wisconsin . . July 22 . . Golf Bowl . . *Annual Outing.*

AUGUST

British Columbia . . Aug. 6 . . Horseshoe Bay . . *Fishing Derby.*

Canton District . . Aug. 6 . . Brookside Country Club, Barberton, Ohio . . *Annual Picnic and Golf Party.*

Chicago . . Aug. 6 . . Nordic Hills Country club, Itasca, Ill. . . *Annual Golf Outing.*

Southern California . . Aug. 6 . . Lakewood Country Club, Lakewood, Calif. . . *Annual Stag Party.*

Foundry Trade News

Ductile Iron Society . . . elected five new directors at its annual meeting held May 11 in Philadelphia. New directors are: S. F. Carter, American Cast Iron Pipe Co., Birmingham, Ala.; N. J. South, American Brake Shoe Co., Medina, N. Y.; B. L. Baptist, Beloit Iron Works; Beloit, Wis.; E. P. Trout, Lufkin Foundry & Machine Co., Lufkin, Texas; and G. W. Phelps, Otaco, Ltd., Ontario, Can.

President R. S. Thompson, H. P. Deuscher Co., Hamilton, Ohio, spoke on the increasing level of ductile iron production. Vice-president William Beatty, Morris Bean Co., Cedarville, Ohio, addressed members on operating items of interest. Cost and operating meetings were discussed by E. C. Graham, Acme Foundry & Machine Co., H. W. Johnson, Wells Mfg. Co., and J. N. Lansing, executive secretary.

Steel Founders' Society . . . has announced chairmen and committee members for the 12 standing committees to serve during the 1960-61 fiscal years. Committees and chairmen are: Advertising & Public Relations, M. J. Allen, American Steel Foundries, Chicago; Bridge Castings Task Force, G. C. Samson, Omaha Steel Works, Omaha, Neb.; Budget, W. H. Moriarty, National Malleable & Steel Castings Co., Cleveland.

Handbook, W. W. Heimberger, Buckeye Steel Castings Co., Columbus, Ohio; Management Accounting Program, H. L. McClees, Crucible Steel Casting Co., Landsdowne, Pa.; Market Research, A. M. Slichter, Pelton Steel Casting Co., Milwaukee; Program Evaluation, C. E. Grigsby, American Steel Foundries, Chicago; Product & Market Development, J. A. Bray, Mackintosh-Hemphill Div., E. W. Bliss Co., Pittsburgh, Pa.; National Policy Information, J. Keith Louden, Lebanon Steel Foundry, Lebanon, Pa.

Safety, J. D. Holtzapple, Blaw-Knox Co., Pittsburgh, Pa. Specifications, R. H. Frank, Bonney-Floyd Co., Columbus, Ohio; Technical & Operating, D. L. Hall, Oklahoma Steel Castings Co., Tulsa, Okla.; Technical Research, V. E. Zang, Unitcast Corp., Toledo, Ohio.

National Foundry Association . . . has moved its offices from Chicago to 4321 St. Charles Road, Bellwood, Ill.

J. W. Hamblen Co. . . . Kenosha, Wis., has been formed by James W. Hamblen, formerly a metallurgical consultant with the Cardox Div., Chemetron Corp., Chicago. The company will do consulting work and serve as manufacturers' representatives.

Inductotherm Linemelt Corp. . . . Delanco, N. J., has entered the core-type and coreless low-frequency induction equipment field. The newly formed organization will manufacture core-type induction melting equipment and has an agreement to handle Swiss-made coreless low frequency melting furnaces in the United States. President J. Lloyd Hoff and vice-president Alfred A. Coley had been associated with Ajax Engineering Corp. The new corporation, although a separate corporation, is associated with Inductotherm Corp.

Cast Aluminum & Brass Corp. . . . San Leandro, Calif., is the new name for Production Castings Co.

New Products and Processes

Build an idea file for improvement and profit. Circle numbers on literature request card, page 139, for manufacturers' information.

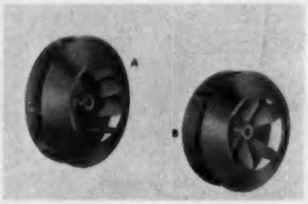
Muller Provides Effective Bond, Maintains Size and Permeability

Continuous muller gives high volume of properly conditioned sand. Mulling action maintains grain size and permeability achieving an effective bond. Intensive mixing and aeration helps to cool sand. Choice of continuous operation or a batch and continuous operation. Available in three sizes up to 30 tons per hr. F. E. North America, Ltd.

For More Information, Circle No. 1, Page 139

Industrial Fan Line Provides Wide Range of Shapes and Arrangements

Industrial fans for handling exhaust gases corrosive fumes and granular materials are available in two blade shapes, a wide range of wheel and inlet sizes and five arrangements to meet most industrial requirements. Air and gas fumes handling wheels



have backwardly-inclined blades for top efficiency (A). For pneumatic conveyor systems, a granular materials handling wheel is available with straight blades (B) to resist abrasive action and wear in such application as foundry sand. Trane Co.

For More Information, Circle No. 2, Page 139

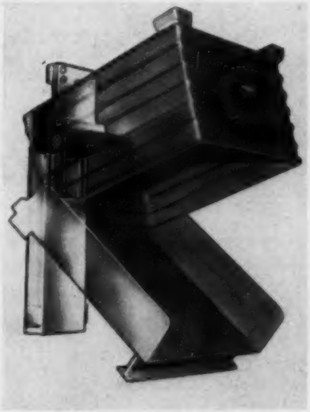
Self-Contained Induction Melting Unit Contains Entire Power Supply

Self-contained induction melting unit contains entire power supply, capacitors, control and safety devices necessary to operate one or two high-frequency induction furnaces or coils. Compact 50 kw motor-generator and control unit contains an eight step auto transformer and a 32-position capacitor switch for maximum flexibility. Installation requires only 60 cycle, 220- or 440-v power connection, cold water connection and water drain. Inductotherm Corp.

For More Information, Circle No. 3, Page 139

Dump-Drop Bottom Boxes Through Use of Fork Lift Hydraulic Unit

Dump drop bottom boxes regardless of make or contents with hydraulic attachment which comes in 4000-



10,000-lb capacity models. Unit, controlled by operator, fits any make and model lift truck; forks remained unchanged. Little Giant Products, Inc.

For More Information, Circle No. 4, Page 139

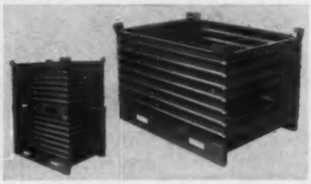
Blender Belt Gives Longer Life and Is 99 Per Cent Self-Cleaning

Blender belt reportedly is superior to standard steel-toothed belt, giving up to 50 per cent more life and is 99 per cent self-clearing. Available in all sizes to fit all types of sand blenders. F. E. (North America) Ltd.

For More Information, Circle No. 5, Page 139

Four-Way Entrance in Corrugated Casting Box Facilities Handling

Corrugated Castings Box has four-way entrance for moving and stacking by fork truck and fork slots side for rotary dumping operations. Construction is all-steel welded with



square corners to provide maximum rigidity in stacking and more interior space. Stacking pockets permit tiering to any height. Box measures 33 x 48 x 24 in. deep. Palmer-Shile Co.

For More Information, Circle No. 6, Page 139

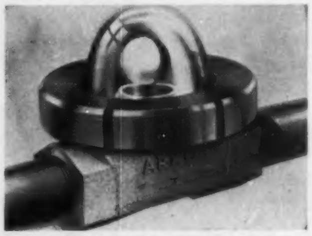
Precision Crane Positioning Made Possible with Hydraulic Instrument

Crane precision positioning made possible by hydraulically-operated instrument between crane hook and load which allows accuracy to 1/1000 in. from one to 100 ton capacities. Final load set is controlled by unit operator who has close visual observation of load. Movements of the load are independent of the crane operator. Rate of descent can be controlled from 0 to 8 ft per min maximum velocity. Mefco Sales & Service Corp.

For More Information, Circle No. 7, Page 139

Dancing Ball in Flow Indicator Reveals Conditions At a Glance

Low flow indicator tells at a glance whether water, air or gas flow is taking place in such applications as cooling water to compressors and lubricating oil to bearings. Ball type indicator is clearly visible from a dis-



tance, the flow makes the ball dance in the toughened glass dome. If the flow stops, the ball drops out of sight. Available in 1/2-in. pipe size for pressures up to 100 psi. McIntosh Equipment Corp.

For More Information, Circle No. 8, Page 139

Automatic Sand System Controls Production, Cuts Sand Spillage

Automation of sand system with elimination of spill sand is a feature of unit which controls production of sand from the mixer and distribution

to multiple molders' hoppers. Centrally controlled system allows for cutting out of any hopper at any time. Hartley Controls Corp.

For More Information, Circle No. 9, Page 139

Automation of Hollow Shell Core Machine Produces 15 Second Cycle

Hollow shell core unit, completely automatic, reportedly has largest core box capacity and highest Btu output of machines in its class. Each core box is individually adjustable for blow, invest, and cure times.

Average cycle of 15 seconds allows one man to operate three machines, stripping up to 240 boxes per hour. Box changes can be made on one unit without affecting production rates on other units. Beardsley & Piper Div., Pettibone Mulliken Corp.

For More Information, Circle No. 10, Page 139

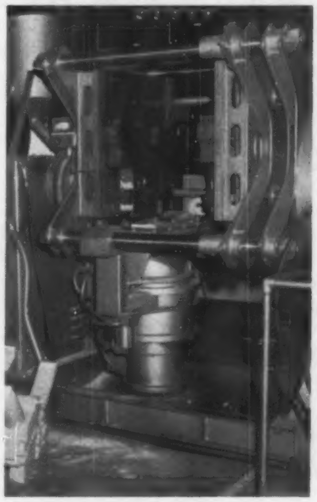
Storage Space Economies Possible with Narrow-Aisle Fork Lift Truck

Storage space economizing made possible with narrow aisle fork lift truck, which works in aisles only 5-1/2 ft wide and stacks to heights of 16 ft. Stacker trucks can be operated either as a walker unit or as a rider-type truck. In addition to standard controls, operations can be remotely controlled from platform at any height. Lewis-Shepard Products, Inc.

For More Information, Circle No. 11, Page 139

Shell Hollow Core Machine Produces Wide Range of Large, Medium Work

Shell hollow core machine with 100 pounds blow capacity produces large shell cores in single cavity boxes or a

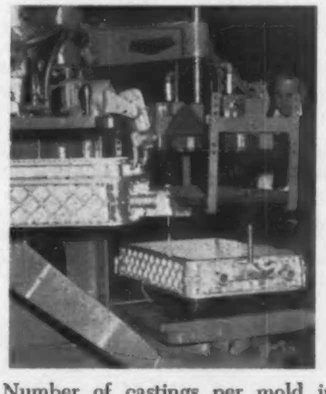


wide range of medium size cores in multi-cavity boxes. All operations of machine are fully automatic except for actual removal of cores. Large platens accommodate core boxes up to 14x24x30 inches. Spo, Inc.

For More Information, Circle No. 12, Page 139

Machine Allows Many Cope and Drag Jobs to be Molded with Match Plate

Molding machine mechanizes match plate handling, Jolt, rollover, squeeze, cope drawing and handling, and closing operations, giving increased accuracy and production. Many short run floor and cope and drag jobs may now be molded with match plate pattern.



Number of castings per mold increases since mold weight and size are not of major consideration. One machine can handle a wide range of flask sizes and is quickly adjustable for rapid job changes. Osborn Mfg. Co.

For More Information, Circle No. 13, Page 139

Air-Operated, Jolt Rollover Draw Units Said to Increase Production

Automatic, air-operated jolt rollover draw molding machine is said capable of increasing production 50 per cent.

Units in 1000, 1500, and 2500-pound sizes are practically dustproof,

oil themselves, and dehydrate the air before using. Draw unit needs no adjusting, seeking its own position and automatically leveling against the flask before drawing the pattern. Davenport Foundry & Machine Co.

For More Information, Circle No. 14, Page 139

Portable Hardness Tester for Large Components Uses C-Clamps

Portable hardness tester for large components and work specimens uses C-clamp brackets with varying throat sizes. Standard Rockwell B and C scale tests are produced by spring loading. Wilson Mechanical Instrument Div., American Chain & Cable

For More Information, Circle No. 15, Page 139

Vacuum Degassing Chamber Treats Ferrous and Non-Ferrous Metals

Vacuum degassing chamber, handling up to 1000 pounds of metal, Completes degassing in six to 15 minutes with metal being poured into molds or ingots in customary manner.

Manufactured by Centrifugal Casting Machine Co., Tulsa, Okla., the unit cleans copper, copper-base alloys, aluminum and ferrous metals. Installation needs no special foundation, only electric power and water supply need connecting.

For More Information, Circle No. 16, Page 139

New Books for You . . .

Work Improvement . . . Guy C. Close, Jr. 388 pp. John Wiley & Sons, Inc., 440 Fourth Ave., New York. 1960. Book tells how to eliminate waste time, energy and material by using the appropriate tools. The analytical application of work sampling and principles of motion economy, the comparative utility of job simplification versus job enlargement, and the use of imaginative thinking are described and explained for all—from foremen to executives—who are interested in work improvement.

A. S. T. M. Standards on Light Metals and Alloys, 5th Edition . . . A. S. T. M. Committee B-7. 358 pp. American Society for Testing Materials, 1916 Race St., Philadelphia. 1959. Book contains three recommended practices, 10 test methods, and 44 specifications covering aluminum-base ingots, castings, bars, rods, wire shapes, forgings, pipe, tubes, sheet, plate, filler metal and wrought products for electrical applications. Magnesium-base alloys are similarly covered. In addition to general test methods there is a standard for electroplating on aluminum alloys.

1959 Supplement to Book of A. S. T. M. Standards Including Tentatives—Part 1, Ferrous Metals (Specifications) . . . 350 pp. American Society for Testing Materials, 1916 Race St., Philadelphia. 1959. Covers steel pipe, steel tubes, steel forged or rolled pipe fittings and welding fittings, steel castings, steel bolting materials, boiler steel plates and rivets, structural and rivet steel, sheet and strip steel, bar steels, steel forgings, concrete reinforcement steel, steel chain, corrosion-resisting and heat-resisting steel, lead- and terne-alloy-coated steel and iron products, zinc-coated steel and iron products, wrought iron, cast iron, ferro-alloys, titanium and titanium alloys.

1959 Supplement to Book of A. S. T. M. Standards Including Tentatives—Part 2, Non-Ferrous Metals (Specifications), Electronic Materials . . . 272 pp. American Society for Testing Materials, 1916 Race St., Philadelphia. 1959. Covers copper and copper-base alloys, lead- and tin-base alloys and antimony, titanium, materials for electrical uses, metal powders, die-cast metals and alloys, aluminum and aluminum-base alloys, magnesium and magnesium-base alloys and metallic electrical conductors.

Directory of Firms, Their Buyers, and Specifying Engineers—Aircraft, Missile, Space, and Electronic Industries in the 11 Western States . . . 130 pp. Industries Publishing Co., Culver City, Calif. 1960. A list of buyers and purchasing agents in the defense industries located in 11 western states.

Ferrous Metallurgy Laboratory Manual . . . Joseph S. Umowski. 83 pp. American Technical Society, Chicago. 1960. A series of laboratory experiments designed to educate students at the vocational, technical high school, and technical institute levels. Also suited for training shop personnel.

Symposium on Electron Metallography . . . 134 pp. American Society for Testing Materials, Philadelphia. 1960. Eleven topics are covered involving the use of electron microscope in studying metals.

Future Meetings and Exhibits

June 26-July 1 . . American Society for Testing Materials, Annual Meeting & Exhibit. Chalfonte-Haddon Hall, Atlantic City, N. J.

June 27-July 1 . . Gordon Research Conferences, Physical Metallurgy-Relation of Structure & Properties. Kimball Union Academy, Meriden, N. H.

July 24-29 . . Pennsylvania State University, Research & Management Development Seminar. University Park, Pa.

Aug. 14-17 . . American Institute of Chemical Engineers and **American Society of Mechanical Engineers,** Heat Transfer Conference & Exhibit. Statler Hilton Hotel, Buffalo, N. Y.

Sept. 6-16 . . National Machine Tool Builders' Association, Machine Tool Exposition. International Amphitheatre, Chicago.

Sept. 14-15 . . American Die Casting Institute, Annual Meeting. Edgewater Beach Hotel, Chicago.

Sept. 19-24 . . International Foundry Congress. Zurich, Switzerland.

Sept. 22-23 . . National Foundry Association, Annual Meeting. Edgewater Beach Hotel, Chicago.

Sept. 27 . . American Management Association, Annual Meeting. Hotel Astor, New York.

Sept. 27-30 . . Association of Iron and Steel Engineers, Annual Convention & Exposition. Public Auditorium, Cleveland.

Oct. 12 . . Cast Bronze Bearing Institute, Annual Meeting. Grove Park Inn, Asheville, N. C.

Oct. 12-14 . . Gray Iron Founders' Society, Annual Meeting. Netherland-Hilton Hotel, Cincinnati.

Oct. 13-15 . . Non-Ferrous Founders' Society, Annual Meeting. Grove Park Inn, Asheville, N. C.

Oct. 14-15 . . AFS New England Regional Foundry Conference. Massachusetts Institute of Technology, Cambridge, Mass.

Oct. 17-18 . . Magnesium Association, Annual Convention. Pick Carter Hotel, Cleveland.

Oct. 17-21 . . American Society for Metals, Annual Meeting and Metal Exposition & Congress. Trade & Convention Center, Philadelphia.

Oct. 17-21 . . National Safety Council, National Safety Congress. Chicago.

Oct. 19-21 . . National Management Association, Annual Meeting. Dinkler Hotel, Atlanta, Ga.

Oct. 20-22 . . Foundry Equipment Manufacturers Association, Annual Meeting. The Greenbrier, White Sulphur Springs, W. Va.

Oct. 21-22 . . AFS Northwest Regional Foundry Conference. Georgia Hotel, Vancouver, B. C.

Oct. 27-28 . . AFS All Canadian Regional Foundry Conference. Mt. Royal Hotel, Montreal, Que.

Oct. 27-28 . . AFS Purdue Metals Casting Conference. Purdue University, Lafayette, Ind.

Nov. 3-4 . . AFS Michigan Regional Foundry Conference. Bancroft Hotel, Saginaw, Mich.

Nov. 14-16 . . Steel Founders' Society of America, Technical & Operating Conference. Carter Hotel, Cleveland.

Let's Get Personal . . .

Alexander Beck . . . formerly general manager and assistant treasurer, Whitman Foundry, Inc., Whitman, Mass., has been promoted to president. He has been associated with Whitman Foundry for 15 years and is a past president of the AFS New England Chapter.


A. Beck


W. Jenkinson

Walter Jenkinson . . . formerly associated with Fairmount Foundry, Inc., Philadelphia, is now foundry superintendent, H. G. Enderlein Co., Philadelphia.

Roy W. Bennett . . . in charge of material sales, Walter Gerlinger, Inc., Milwaukee, has been elected vice-president and **Donald M. Gerlinger,** in charge of equipment and engineering, has been elected vice-president and treasurer. **Walter Gerlinger** was re-elected to the board of directors and president.

John Smillie . . . formerly laboratory technician, John Deere & Co., Moline, Ill., is now development engineer, Lakey Foundry Corp., Muskegon, Mich.

Robert T. Ferguson . . . has been named as technical manager of pig and ingot sales, Aluminum Co. of America, and **Frederick C. Irving, Jr.,** as technical manager of casting sales. Ferguson has


F. C. Irving


J. C. McIlhargey

been assistant chief smelting division metallurgist since 1955 and Irving has been production assistant in the fabricating division since 1957.

Paul W. Olson . . . formerly general manager, Eaton Mfg. Co. Foundry Div., Vassar, Mich., has been appointed to a similar position at the Marion Forge Div., Marion, Ohio, succeeding **T. A. Moretti,** transferred to special assign-

Circle No. 146, Page 139

ments. **George R. Frye,** formerly factory manager of the foundry division, has been promoted to general manager, succeeding Olson.

Frank G. Steinebach . . . has been advanced to publisher and editorial director of *Foundry* magazine. Replacing Steinebach as editor is William G. Gude, formerly managing editor.

C. Eugene Silver . . . is now sales service representative in Texas and Louisiana for the Osborn Mfg. Co. molding machine division. He will headquarter in Houston, Texas. **Ray F. Frings,** Birmingham, Ala., has been named sales and service representative in Alabama, Florida, Georgia, Mississippi, North Carolina, and South Carolina.

Albert J. Primosic . . . has been advanced to manager of operations, Keokuk Electro-Metals Co., Div. Vanadium Corp. of America. He had been manager of the Vanadium Corp. Niagara Falls plant since 1957. Keokuk Electro-Metals Co. merged into Vanadium Corp. in 1959.

E. G. Tetzlaff . . . formerly with Pelton Steel Castings Co., Milwaukee, has joined Texas Foundries, Inc., Lufkin, Texas, as assistant plant manager. **Charles J. Angers,** formerly with Crucible Steel Castings Co., Cleveland, has been appointed superintendent of the steel division.

Vernon Gornick . . . has been named as sales representative in Wisconsin and northern Illinois, and **Howard Johnson** named sales representative in Indiana and Ohio for Tennessee Products & Chemical Corp.

E. G. Weissenberger . . . formerly with Pyro Electric Co., Walkerton, Ind., is now a product division manager of Claud S. Gordon Co., Chicago.

Stanley Abkowitz . . . is now manager of refractory metals product development, Metals Div., Kelsey-Hayes Co., New Hartford, N. Y. He previously was staff metallurgist, Mallory-Sharon Metals Corp., Niles, Ohio.

obituaries

Robert D. Noyes, assistant division manager, Union Carbide Plastics Co., Div., Union Carbide Corp., and a member of the AFS Metropolitan Chapter, died June 1.

William B. Goltra, 58, owner of Goltra Steel Foundries, Barrington, Ill., died in May at his home. He was associated with American Steel Foundries for 17 years, starting in 1929 and serving in a sales capacity from 1936 until his retirement in 1946. Goltra then started his own company, pioneering in the development of small, specialized steel castings.

Joseph S. Mohr, General Refractories Co. regional sales manager, Chicago, died in his home on May 22. He had served in the company's Chicago post since 1935.

Austin T. Lillegren, 67, vice-president, Madison-Kipp Corp., Madison, Wis., die casting firm, died May 14 in a Madison hospital. He was serving as chairman of the Die Casting Research Foundation and was also on the American Die Casting Institute Board of Directors.

George A. Pope, 54, business manager, "Foundry" magazine, died May 31 in Cleveland. Pope started with the Penton Publishing Co. in 1930 in the Foundry circulation department, leaving in 1933. He returned in 1936 to Penton Publishing and in 1940 headed the Chicago Foundry operations. He returned to Cleveland in 1950 as Foundry business manager.

"This H-25 PAYLOADER® is a key machine in our operation"*

***Mr. Bill Roberts, V. P. of The Markey Bronze Bushing Company at Delta, Ohio, says,** *"We couldn't cut sand and haul back to our molders without our H-25. It's a key part of our operation. It would take at least seven more men to replace it in the sand operation alone."*

John Stromberger, General Plant Foreman adds, *"I like the roll-back action of that bucket. Our operators like the machine and it gives good service. It handles easily, and is very maneuverable — working in and out of tight places well."*

Increasing production demands at The Markey Bronze Bushing Company resulted in the replacement of an old Model HA "PAYLOADER" with a Model H-25. This new tractor-shovel with its greater operating capacity (2,500 lbs.) power-shift and power-steer provided the required production boost along with easier operation. It has won the approval of management and machine operators alike and, in spite of its larger capacity, has an even shorter turning radius (6 ft.) than the HA. It delivers sand to the molding stations and to hoppers . . . handles bronze scrap and other materials . . . does plant maintenance in the machine shop and foundry . . . hauls machinery.

A Size for Any Job: The model H-25 is one of many modern and proven "PAYLOADER" tractor-shovels including 4-wheel-drive types up to 12,000 lb. operating capacity — a size for any materials handling job, indoors or outdoors.

HOUGH®

THE FRANK G. HOUGH CO.
LIBERTYVILLE, ILLINOIS
SUBSIDIARY — INTERNATIONAL HARVESTER COMPANY

THE FRANK G. HOUGH CO. 7-A-3
711 Sunnyside Ave., Libertyville, Ill.
Send data on all "PAYLOADER" models and attachments.

Name ______________________
Title ______________________
Company ______________________
Street ______________________
City ______________ State ______

Circle No. 149, Page 139

How's Business . . .

Metalcastings business for the last 12 months, March 1959-February 1960, continues to run well ahead of the previous 12-month period. The horizontal bar charts on this page and the next visually demonstrate this.

A comparison of current and past performance of the individual metals shows gray iron running 14 per cent ahead of the previous 12-month period, malleable iron is up 34 per cent, steel 30 per cent, aluminum 28 per cent, copper 21 per cent, and zinc 32 per cent.

A look at the right-hand set of curves shows how each month's shipments compare with the same month the year before. When the curve is above the 100 per cent line, the industry is shipping more than last year, and vice versa.

Gray iron dropped off rather sharply in February while zinc casting continued the upward trend it started in November. The other metals seem to be holding their own on a plateau at the 100 per cent line.

The latest report from the Bureau of Census reveals castings shipments for all metals in March are above February, except zinc and magnesium. Outstanding was an 11 per cent increase in steel castings which totaled 144,000 tons in March.

The Trend is Up . . .

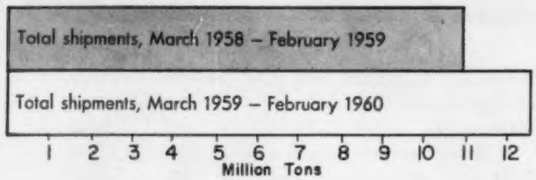
Plant and equipment investment continues upward . . . in 1959 it was $32-1/2 billion . . . at the end of first quarter 1960 annual rate was up to $35 billion . . . a $37 billion and $37-1/2 rate is expected in the second and third quarters (U. S. Department of Commerce Report). This is good news for foundries. More castings are needed when railroad, automotive, machinery, mining, public utilities and manufacturing industries increase their capital outlays for new facilities. If foundrymen capture their share of these expanding markets, a profitable 1960 should be guaranteed.

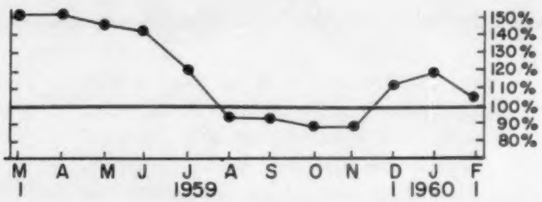
Federal Government has embarked on a big drive to boost U. S. exports to close the gap in the balance of trade caused by larger imports. Exporters will be assisted by Federal guarantees for partial repayment of short-term credits extended to foreign customers and improvement in U. S. trade services overseas. Pep-talks are being given to business executives.

Trends in Metalcastings Shipments

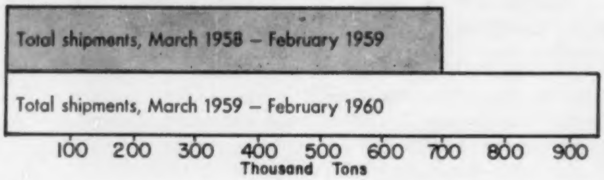
Statistics from Bureau of the Census, U. S. Department of Commerce

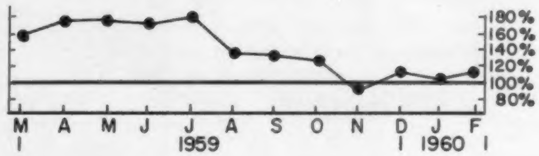
GRAY IRON



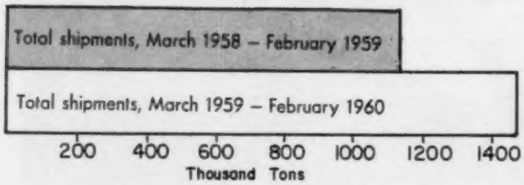


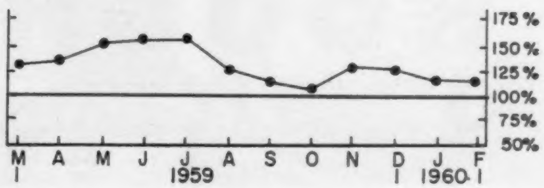
MALLEABLE IRON





STEEL





Better business in second half of 1960 was predicted by National Association of Purchasing Agents. "Prices are on a plateau, held down by adequate domestic productive capacity and the threat from foreign manufacturers, and held up by high materials costs and increasing labor rates," the association stated.

Textile machinery builders are enjoying a boom sparked by strong modernization trend in the industry. Textile mills are rising to meet competitive imports by cutting costs with more modern equipment. Foundries supplying castings for this segment of the industrial complex should experience heavy demand throughout 1960.

Unfair Trade Practices

Some imported plumbing brass goods are failing to meet the established standards of identification, rigid specifications and inspection. As a result of action by the Plumbing Brass Institute, the Bureau of Customs now requires importers to place the country of origin legibly and conspicuously on imported products. The trade association has resolved that all plumbing brass goods made in this country be clearly marked with "U. S. A."

Business Barometers . . .

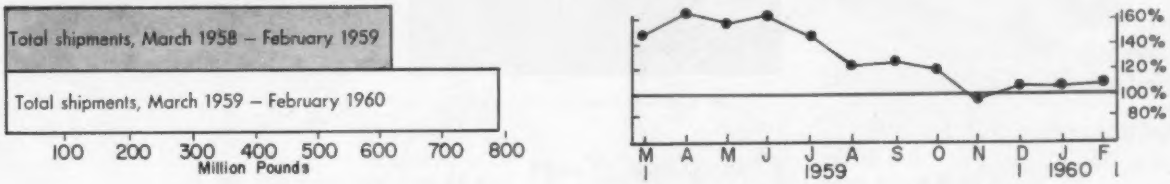
Price of aluminum alloy ingot made from scrap by smelters was cut one cent a pound early in June. Slow demand from die casters and other foundry users led to the reduction.

All eyes are on the steel industry —barometer of what's in store for the metalcasting industry. No other weekly business statistic is quite so indicative of general business conditions. Early in June steel production had slipped to 61 per cent of capacity. Predictions are that second half of 1960 will average about 75 per cent. Many big steel users are working from inventories which were built up earlier in the year to levels now considered excessive.

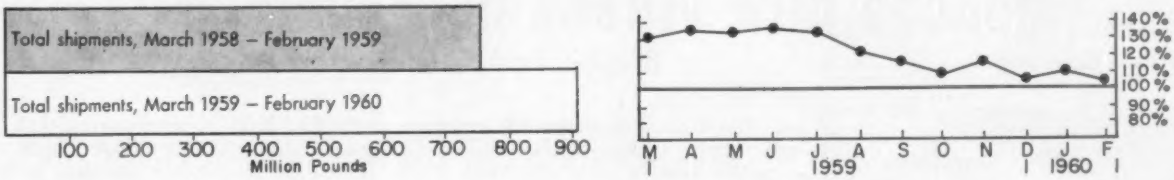
A $400,000 customer-service laboratory designed to assist magnesium die casters was announced by The Dow Chemical Co. Customers will be invited to send engineering and production personnel to the lab for training in melting and casting of magnesium.

Over $331,000,000 of "large loss" industrial fires occurred in 1959—according to National Fire Protection Association. Building construction weaknesses and absence of protective sprinkler and alarm systems were main reasons why minor fires got out of hand and turned into major industrial losses.

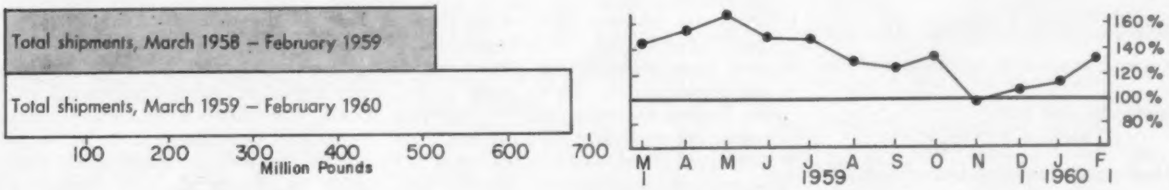
ALUMINUM



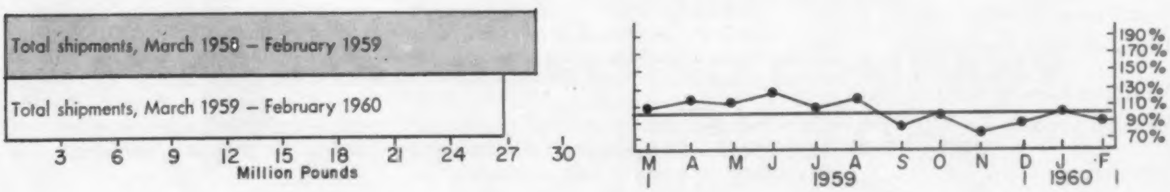
COPPER



ZINC



MAGNESIUM



Advertisers This Issue

The Adams Co. 6
Ajax Magnethermic Corp. 49
Apex Smelting Co. 137
Archer-Daniels-Midland Co. .. 12, 13

Beardsley & Piper–
Div. Pettibone Mulliken Corp. 11

Carver Foundry Products Co. .. 1
Cast Masters, Inc. 141
The Cleveland Flux Co. 131
Combined Supply & Equipment
Co., Inc. 132

F.E. North America, Ltd. 116

Hanna Furnace Corp. Div. of
National Steel Corp. 22, 23
Hevi-Duty Electric Co., Div. of
Basic Products Corp. 121
The Frank G. Hough Co. 133

The International Nickel
Co., Inc. .... 2nd Cover

Keokuk Electro-Metals Co.,
Div. of Vanadium Corporation
of America 14

Metal Blast, Inc. 125
Modern Equipment Co. 2

National Engineering Co. 3rd Cover

Ohio Ferro-Alloys Corp. 115
Oliver Machinery Co. 132

Philadelphia Quartz Co. 19
Pickands Mather & Co. 26

Reichhold Chemicals, Inc. 4th Cover
Royer Foundry & Machine Co. 15

Semet Solvay Div.
Allied Chemical Corp. 4
Frederic B. Stevens, Inc. 9, 127
Syntron Co. 10

Union Carbide Metals Co., Div.
of Union Carbide Corp. 21
Universal Clay Products Co. .. 20

Vanadium Corp. of America 18
Vesuvius Crucible Co. 17

Wheelabrator Corp. 16

Die casting ejects onto sliding fixture which places it on conveyor.

Our July Cover . . .

75-hp Die Cast Aluminum Block for Outboard Motors

The largest aluminum die casting in mass production today is pictured on this month's cover—the 34-lb, 75-hp, V-4 block for outboard motors. Twenty-six pounds of 88 Al-12 Si alloy are shot around four iron cylinder liners and a bronze main bearing insert.

Johnson Motors, Division of Outboard Marine Corp., Waukegan, Ill., casts these blocks in the largest captive aluminum die casting foundry in the United States—a 316,000 square foot plant with over 100 die casting machines. Plant casts 3-1/2 million pounds of aluminum a month. In addition to cast blocks for engines ranging from 75 hp down to 3 hp, Johnson die casts cylinder heads, crankcases, stern brackets, exhaust housings, propellers, gear cases, handles and brackets, flywheels, and parts of shrouds.

To make this whopping 34-lb block, Johnson Motors ordered the largest unit-frame die casting machine ever built. It features such superlatives as: 1200-ton locking pressure; 47-1/2 pounds of aluminum per shot; 20,300 pounds per square inch maximum injection pressure; dies 4-1/2 feet high by 6 feet wide, opening to 3 feet.

Machine is equipped with automatic ladling device which delivers exact weight of metal needed for each shot. Because of the casting weight, handling had to be mechanized. Plant engineers designed a sliding fixture that moves in, takes the casting, retracts, and places it on inclined conveyor. All the die casting metal is melted by induction and each machine is equipped with induction holding furnaces.

Outboard motors are big business. Last year, over 540,000 outboard motors were manufactured and sold for an estimated $255,000,000. Outboards serve more than recreational needs. They are used in commercial fishing, conservation, flood relief work, rescue and patrol activities of military and police, trapping, surveying, and logging.

Circle No. 150, Page 139

For The Asking

Build an idea file for improvement and profit. Circle numbers on literature request card for manufacturers' publications.

Service manual . . . for lightweight air hoists now available when you use the circle number below. Thor Power Tool Co.
For Your Copy, Circle No. 49, Page 139

Pierced metal . . . and slit screens have many industrial applications. For typical screen assemblies, ask for 12-p brochure. Cross Perforated Metals Plant, National-Standard Co.
For Your Copy, Circle No. 50, Page 139

Industrial insulations . . . line manufactured by new corporation, presented in catalog. Baldwin-Ehret-Hill, Inc.
For Your Copy, Circle No. 51, Page 139

Design contest . . . for gray iron castings explained completely in brochure which includes official entry blank. Gray Iron Founders' Society, Inc.
For Your Copy, Circle No. 52, Page 139

Centrifugal casting . . . of non-ferrous metals offers advantages listed in brochure which features specifications of cast products. Centrifugally Cast Products Div., Shenango Furnace Co.
For Your Copy, Circle No. 53, Page 139

Carbon additive . . . reportedly is a one-unit package combination offering effectiveness of cellulose and seacoal. Request folder. American Colloid Co.
For Your Copy, Circle No. 54, Page 139

Hardness conversion . . . chart shows approximate relation between hardness by various testing systems and tensile strength of carbon and alloy steels. Babcock & Wilcox.
For Your Copy, Circle No. 55, Page 139

Chromatographic . . . apparatus and supplies for gas, paper and column chromatography presented in 28-p book. Schaar and Co.
For Your Copy, Circle No. 56, Page 139

Metalcasting technology . . . experts have written many books and manuals which are available through AFS. A complete, classified list is yours when you use the circle number below. American Foundrymen's Society.
For Your Copy, Circle No. 57, Page 139

Your invention . . . could be useful for the armed forces; for a 44-p pamphlet spelling out new problems facing the armed forces, use the circle number below. National Inventors Council, U. S. Dept. of Commerce.
For Your Copy, Circle No. 58, Page 139

Shell investment . . . mold furnace designed for high firing shell investment molds described on data sheet. Alexander Saunders & Co.
For Your Copy, Circle No. 59, Page 139

Copper-base alloys . . . discussed in free reprints of talks presented before American Society for Testing Materials. Brass & Bronze Ingot Institute.
For Your Copy, Circle No. 60, Page 139

Infrared heating . . . oven components; quartz tubes, metal rods and quartz lamps covered in brochure. Fosteria Corp.
For Your Copy, Circle No. 61, Page 139

Vibrating feeders . . . operating on motorized counterweight principle now have 49 new sizes added to line. Capacities are up to 1700 tons per hour. Request new 12-p book. Link-Belt Co.
For Your Copy, Circle No. 62, Page 139

What is service . . . and how can you teach your staff to be service-minded? Read about it in government publication. Small Business Administration.
For Your Copy, Circle No. 63, Page 139

Forty-two ways . . . to transfer materials on conveyor systems are enumerated in collection of technical papers. Rapids-Standard Co.
For Your Copy, Circle No. 64, Page 139

High alloy . . . heat resistant castings for applications where temperatures exceed 1200 F are discussed in article primarily concerning selection of these alloys. Alloy Casting Institute.
For Your Copy, Circle No. 65, Page 139

Combination . . . wall chart and pamphlet of available temperature–indicating paints and crayons. Princeton Div., Curtiss-Wright Corp.
For Your Copy, Circle No. 66, Page 139

Gamma radiography . . . used to determine internal soundness of a casting. Request brochure. Curtiss-Wright Corp.
For Your Copy, Circle No. 67, Page 139

Molybdenum . . . products bulletin gives information of a non-technical nature for executives, purchasing agents and others with a general interest. Covers sizes, forms, conditions of use, tolerances, etc. of products available for commercial use. Climax Molybdenum Co.
For Your Copy, Circle No. 68, Page 139

Complete survey . . . of aluminum welding, brazing and soldering presented in manual. All-State Welding Alloys Co.
For Your Copy, Circle No. 69, Page 139

Compressors . . . pumps, condensing equipment, vacuum equipment and air hoists specified in new booklet. Ingersoll-Rand.
For Your Copy, Circle No. 70, Page 139

Scrap handling . . . is subject of bulletin featuring new line of lifting magnets designed for handling of scrap. Stearns Magnetic Products.
For Your Copy, Circle No. 71, Page 139

Thermocouple . . . assemblies described in detail in new 40-p catalog; over 100 assemblies covered. Minneapolis-Honeywell Regulator Co.
For Your Copy, Circle No. 72, Page 139

Pressure and temperature . . . recorders described in new catalog. U. S. Gauge Div., American Machine & Metals, Inc.
For Your Copy, Circle No. 73, Page 139

Solve dock layout problems . . . through an engineered approach. Send for free freight handling analysis form. Lewis-Shepard Products, Inc.
For Your Copy, Circle No. 74, Page 139

Guide to silicones . . . and their uses in foundries and industry in general presented in 16-p brochure. Dow Corning Corp.
For Your Copy, Circle No. 75, Page 139

Self-dumping hoppers . . . for handling of bulk materials. New brochure, 4 pp, is yours when you circle number below on Literature Request Card. Apex Welding & Fabricating Corp.
For Your Copy, Circle No. 76, Page 139

Tooling materials . . . technical data bulletin No. T1A discusses comparative data, application check list, and presents a hardener selector. Hysol Corp.
For Your Copy, Circle No. 77, Page 139

Blast cleaning . . . functions and materials covered in new booklet, 30 pp. Discusses new products, materials, standards, specifications and analysis. National Metal Abrasive Co.
For Your Copy, Circle No. 78, Page 139

Technical data . . . catalog free. Revised listing of pocket-size books covering every field of engineering. Lefax Publishers.
For Your Copy, Circle No. 79, Page 139

CO_2 process . . . handbook illustrates equipment and describes process, 46 pp. Carver Foundry Products Co.
For Your Copy, Circle No. 80, Page 139

New self-curing sand binder . . . fully described in 8-page technical bulletin. Archer-Daniels-Midland Co.
For Your Copy, Circle No. 81, Page 139

CO_2 process . . . for making molds and

LITERATURE REQUEST SERVICE

Advertised Products July—1960

	Page Numbers
Abrasives, Blasting	16, 125
Alloys (See Metals, Alloys, Fluxes)	
Chaplets	132
Coke	4, 26
Core Blowers & Shooters	1, 116
Cupola Accessories	2
Flasks	6
Fluxes (See Metals, Alloys, Fluxes)	
Furnaces	49, 121
Ladles & Supplies	17
Material Handling	3d cover, 10, 133
Metals, Alloys, Fluxes	2d cover, 14, 18, 21, 22, 23, 115, 131, 137
Molding Equipment	1, 11
Parting Agents	127
Patternmaking Equipment	132
Patterns	141
Refractory Mold Materials	20
Sand Binders—Resin	4th cover
Sand Binders—Self Curing	12, 13
Sand Binders—Sodium Silicate	19
Sand Conditioning Equipment	9, 15

Yours . . . For Advancing Metalcasting

Are you looking for information on any of the subjects listed in the left hand column? Our MODERN CASTINGS advertisers have carefully prepared important material on each of these topics to help advance your metalcasting practices. You will find it on the page shown opposite the subject of your interest.

Technical literature is also available on these and many other subjects. Just circle the correct number on the card below that corresponds to the Circle No. shown with each ad and new products items in "New Products and Processes" and "For the Asking" departments.

Here's your opportunity to build a valuable reference file of new products, processes, and techniques.

JULY 1960—2

Valid through Oct. 1960

NEW EQUIPMENT AND MATERIALS

1	13	25	37	49	61	73	85	97	109
2	14	26	38	50	62	74	86	98	110
3	15	27	39	51	63	75	87	99	111
4	16	28	40	52	64	76	88	100	112
5	17	29	41	53	65	77	89	101	113
6	18	30	42	54	66	78	90	102	114
7	19	31	43	55	67	79	91	103	115
8	20	32	44	56	68	80	92	104	116
9	21	33	45	57	69	81	93	105	117
10	22	34	46	58	70	82	94	106	118
11	23	35	47	59	71	83	95	107	119
12	24	36	48	60	72	84	96	108	120

☐ I wish to subscribe to MODERN CASTINGS

ADVERTISED PRODUCTS

121	133	145	157	169	181	193	205
122	134	146	158	170	182	194	206
123	135	147	159	171	183	195	207
124	136	148	160	172	184	196	208
125	137	149	161	173	185	197	209
126	138	150	162	174	186	198	210
127	139	151	163	175	187	199	211
128	140	152	164	176	188	200	212
129	141	153	165	177	189	201	213
130	142	154	166	178	190	202	214
131	143	155	167	179	191	203	215
132	144	156	168	180	192	204	216

PLEASE PRINT

Name

Position

Company

Address

No Postage Stamp Necessary If Mailed in the United States

BUSINESS REPLY CARD
First Class Permit No. 83, Sec. 34.9 P. L. & R.
DES PLAINES, ILL.

Reader Service Dept.
MODERN CASTINGS
Golf and Wolf Rds.
Des Plaines, Ill.

LITERATURE REQUEST SERVICE

Yours . . . For Advancing Metalcasting

Are you looking for information on any of the subjects listed in the right hand column- Our MODERN CASTINGS advertisers have carefully prepared important material on each of these topics to help advance your metalcasting practices. You will find it on the page shown opposite the subject of your interest.

Technical literature is also available on these and many other subjects. Just circle the correct number on the card below that corresponds to the Circle No. shown with each ad and new products items in "New Products and Processes" and "For the Asking" departments.

Here's your opportunity to build a valuable reference file of new products, processes, and techniques.

Advertised Products July—1960

Subject	Page Numbers
Abrasives, Blasting	16, 125
Alloys (See Metals, Alloys, Fluxes)	
Chaplets	132
Coke	4, 26
Core Blowers & Shooters	1, 116
Cupola Accessories	2
Flasks	6
Fluxes (See Metals, Alloys, Fluxes)	
Furnaces	49, 121
Ladles & Supplies	17
Material Handling	3d cover, 10, 133
Metals, Alloys, Fluxes	2d cover, 14, 18, 21, 22, 23, 115, 131, 137
Molding Equipment	1, 11
Parting Agents	127
Patternmaking Equipment	132
Patterns	141
Refractory Mold Materials	20
Sand Binders—Resin	4th cover
Sand Binders—Self Curing	12, 13
Sand Binders—Sodium Silicate	19
Sand Conditioning Equipment	9, 15

PLEASE PRINT

Name

Position

Company

Address

No Postage Stamp Necessary If Mailed in the United States

BUSINESS REPLY CARD
First Class Permit No. 83, Sec. 34.9 P. L. & R.
DES PLAINES, ILL.

Reader Service Dept.
MODERN CASTINGS
Golf and Wolf Rds.
Des Plaines, Ill.

JULY 1960—1

Valid through Oct. 1960

NEW EQUIPMENT AND MATERIALS

1	13	25	37	49	61	73	85	97	109
2	14	26	38	50	62	74	86	98	110
3	15	27	39	51	63	75	87	99	111
4	16	28	40	52	64	76	88	100	112
5	17	29	41	53	65	77	89	101	113
6	18	30	42	54	66	78	90	102	114
7	19	31	43	55	67	79	91	103	115
8	20	32	44	56	68	80	92	104	116
9	21	33	45	57	69	81	93	105	117
10	22	34	46	58	70	82	94	106	118
11	23	35	47	59	71	83	95	107	119
12	24	36	48	60	72	84	96	108	120

☐ I wish to subscribe to MODERN CASTINGS

ADVERTISED PRODUCTS

121	133	145	157	169	181	193	205
122	134	146	158	170	182	194	206
123	135	147	159	171	183	195	207
124	136	148	160	172	184	196	208
125	137	149	161	173	185	197	209
126	138	150	162	174	186	198	210
127	139	151	163	175	187	199	211
128	140	152	164	176	188	200	212
129	141	153	165	177	189	201	213
130	142	154	166	178	190	202	214
131	143	155	167	179	191	203	215
132	144	156	168	180	192	204	216

cores discussed in booklet authored by reported authority in field of foundry facings. Frederic B. Stevens, Inc.
For Your Copy, Circle No. 82, Page 139

Refractories . . . handbook, 130 pages, has been completely revised. Includes new products. Walsh Refractories Corp.
For Your Copy, Circle No. 83, Page 139

Drafting equipment . . . and supply catalog, 100 pages, features all equipment and supplies for modern drafting work. Alfred Mossner Co.
For Your Copy, Circle No. 84, Page 139

Responsibility accounting . . . is a term to describe separate accounting reports of individual executives' operating performances. Read about it in government bulletin. Small Business Administration.
For Your Copy, Circle No. 85, Page 139

Reference chart . . . specifies 55 of the more widely used cast alloys in carbon, low alloy, and stainless groups; also nickel and monel. Lebanon Steel Foundry.
For Your Copy, Circle No. 86, Page 139

Metal products facilities . . . for producing products in magnesium, aluminum, and other metals described in new brochure. Dow Chemical Co.
For Your Copy, Circle No. 87, Page 139

Nickel alloys . . . for construction machinery. Four sections of brochure deal with properties of materials, power components, motive units, and machinery. International Nickel Co.
For Your Copy, Circle No. 88, Page 139

Output verification . . . of power tools is subject of new program developed to make complete verification possible. Request literature by using the circle number below. Skidmore-Wilhelm Mfg. Co.
For Your Copy, Circle No. 89, Page 139

Specifications index . . . designed to save time in specifying copper, brass, bronze, nickel silver, and special alloys. American Brass Co.
For Your Copy, Circle No. 90, Page 139

Steel storage equipment . . . such as angle shelving, steel lockers and cabinets, wire basket storage units, etc., illustrated in 8-page catalog. Penco Div., Alan Wood Steel Co.
For Your Copy, Circle No. 91, Page 139

Lift truck attachments . . . brochure shows 24 of the newest attachments being used in industry today. Little Giant Products, Inc.
For Your Copy, Circle No. 92, Page 139

Hoist specifications . . . for manually lever operated chain hoists has recently been released by the Hoist Manufacturers Association.
For Your Copy, Circle No. 93, Page 139

Narrow aisle operation . . . is a feature built into this new single wheel drive lift truck. Request literature. Raymond Corp.
For Your Copy, Circle No. 94, Page 139

Refractories . . . for every foundry need offered in new 8-page bulletin. Special sections devoted to specific types of refractories used for cupolas, electric furnaces, malleable furnaces, non-ferrous metal furnaces, and pouring equipment. Harbison-Walker Refractories Co.
For Your Copy, Circle No. 95, Page 139

Direct recording . . . oscillograph presented in new 36-page manual designed as reference guide for engineers and scientists. Minneapolis-Honeywell Regulator Co.
For Your Copy, Circle No. 96, Page 139

High alloy castings . . . technical publication list offers 46 technical papers, articles, reprints, and data sheets concerning such castings. Alloy Casting Institute.
For Your Copy, Circle No. 97, Page 139

Dielectric core ovens . . . bulletin shows company's full line and presents many installations in prominent foundries. Foundry Equipment Co.
For Your Copy, Circle No. 98, Page 139

New sand binder . . . features elimination of oven baking. Cores made one day can reportedly be cast the next without oven drying. Ask for folder. G. E. Smith, Inc.
For Your Copy, Circle No. 99, Page 139

Crucible furnaces . . . single burner, tilting type, described and specified in 4-page brochure. Campbell-Hausfeld Co.
For Your Copy, Circle No. 100, Page 139

Induction heat . . . equipment and usage is illustrated in this film. 16 mm, color, sound, 20 minutes, free. Allis-Chalmers.
For Your Copy, Circle No. 101, Page 139

Flow process chart . . . and how to use it is shown in this film demonstrating preparation of chart to study and apply work simplification. Sound, color, 16 mm, 15 minutes, rental. United World Films, Inc.
For Your Copy, Circle No. 102, Page 139

Barge freight . . . loading and unloading of cargo to and from barges is subject of film which also shows equipment designed to carry special cargoes. Sound, color, 16 mm, 31 minutes, free loan. Union Barge Line Corp.
For Your Copy, Circle No. 103, Page 139

"How to order" . . . brochure details standard markings for grinding wheels, shapes, and abrasives. "American" Emery Wheel Works.
For Your Copy, Circle No. 104, Page 139

Continuous carbon injection . . . in an acid cupola to control carbon content is subject of technical report reprinted from AFS TRANSACTIONS. American Foundrymen's Society.
For Your Copy, Circle No. 105, Page 139

High-speed melting . . . Read about how a pump manufacturer, unable to find melting equipment to meet the company's needs, decided to build its

Classified Advertising

For Sale, Help Wanted, Personals, Engineering Service, etc., set solid . . 35c per word, 30 words minimum, prepaid.
Positions Wanted . . 10c per word, 30 words minimum, prepaid. Box number, care of **Modern Castings,** counts as 10 words.
Display Classified . . Based on per-column width, per inch . . 1-time, $22.00 6-time, $20.00 per insertion; 12-time, $18.00 per insertion; prepaid.

HELP WANTED

INDUSTRIAL ENGINEER

With the necessary experience, background and interest to establish and head up the Industrial Engineering Department for a large gray iron and malleable foundry. Must be throughly familiar with standards, estimating, incentive wage payments and process engineering. **Box G-103, MODERN CASTINGS, Golf & Wolf Roads, Des Plaines, Ill.**

CORE ROOM FORMAN
$650.00 to $750.00

Excellent opportunity for advancement in a young growing organization, interested in man with top management potential. Client assumes all expenses. Contact Bill Newell in confidence.

MONARCH PERSONNEL
28 East Jackson Blvd. Chicago 4, Illinois

METALLURGIST — Sand Knowledge Degree or sufficient experience in metallurgy to handle carbon, low and high alloy steels. Familiar with acid and basic arc and induction furnace. Also, knowledge of sand and sand formulation. **Post Office Box 8, Station "E", Toledo 9, Ohio.**

SALES REPRESENTATIVE — calling on defense and commercial work — representing investment castings. Need serveral men for midwest area. **Box G-101, MODERN CASTINGS, Golf & Wolf Roads, Des Plaines, Ill.**

METALLURGIST: 24 — 30 years — Some experience. For small plant in Western Michigan, Gray iron Specialties. Splendid opportunity and future for right man, willing to assume responsibilities. Send complete resume in first letter. **Box G-102, MODERN CASTINGS, Golf & Wolf Roads, Des Plaines, Ill.**

WORKING FORMAN for small non-ferrous foundry producing commercial and aircraft quality castings. Must be thoroughly qualified and have background in both sand and permanent mold castings. Excellent opportunity. **Qualco Castings Corporation, P. O. Box 526, Acworth, Georgia.**

Foundry Foreman—For portable slinger molding floor. Must have sound technical and supervisory experience for production of steel castings weighing to 7-1/2 tons. This is a permanent position with a well established and progressive concern. Please submit complete resume to: **Ralph C. Steinmeyer, Crucible Steel Casting Co., 2850 South 20th Street, Milwaukee 15, Wis.**

PLANT ENGINEERS

Experienced on layout of all types of foundry equipment, material handling and material flows. Send complete details on work history, education and family status. Include recent photograph. All replies confidential. **Box F-140, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

WANTED — FOUNDRY SUPERINTENDENT for a small capacity Electric Steel Foundry. This is a foreign assignment for a three year engagement. Living conditions are good. Salary $18,000 per year, first class passage and 3 months terminal leave with pay on completion of engagement. Superintendent must be a competent Steel Metallurgist and experienced Electric Furnace Operator. In reply please give full outline of past experience, age, whether married or single. **Overseas Industrial services, 681 Market Street, San Francisco 5, California.**

PLANT ENGINEER
$11,000 to $13,000

Progressive midwestern foundry that places a high degree of value on organizational proficiency, seeking man to assume complete charge of new installations and maintenance. Company will assume all expenses. Contact Bill Newell in confidence.

MONARCH PERSONNEL
28 East Jackson Blvd. Chicago 4, Illinois

POSITIONS WANTED

GRADUATE ENGINEER — Thirteen years progressive experience in Gray and Malleable iron operations. Primary experience in melting, heat treating and sand control. Familiar with all phases of foundry technology. Position desired — Service or Sales Engineer serving the foundry industry. Age 34 **Box G-100, MODERN CASTINGS, Golf & Wolf Roads, Des Plaines, Ill.**

MANAGER — SUPERINTENDENT — Ferrous and/or nonferrous, 39 years old, 13 years extensive foundry experience. B.S. Degree, Metallurgical Engineering. Qualified to handle all phases of foundry operations. Detailed resume on request. **Box F-104, MODERN CASTINGS, Golf & Wolf Roads, Des Plaines, Ill.**

SUPERINTENDENT-MANAGER—Completely familiar with all foundry phases of cast iron, aluminum brass. 28 years experience in all departments up to Plant Supt., personnel, purchasing, and sales. Also general manager small jobbing non-ferrous shop. Prefer salary plus bonus incentive. Age 44. Presently employed. **Box G-106, MODERN CASTINGS, Golf & Wolf Roads, Des Plaines, Ill.**

GRADUATE METALLURGIST, 16 years experience in carbon, alloy and stainless steels, induction and arc melting, machine, bench and floor molding, heat treating etc., desires more responsible position and challenge. **Box F-103, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

FOUNDRYMAN—Ten years supervisory experience in ferrous and non-ferrous foundry industry. Technical background in metallurgy, chemistry, sand technology, and quality control. Desire technical or sales and service position. Detailed resume on request. **Box G-107, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

ENGINEERING SERVICES

GOOD FOUNDRYMEN

when you need SUPERVISORY or TECHNICAL men why not consult a man with actual foundry experience plus 15 years in finding and placing FOUNDRY PERSONNEL.
Or if you are a FOUNDRYMAN looking for a new position you will want the advantages of this experience and close contact with employers throughout the country.

For action contact: John Cope
DRAKE PERSONNEL, INC.
29 E. Madison St., Chicago 2, Illinois
Financial 6-8700

EARL E. WOODLIFF
Foundry Sand Engineer
Consulting . . . Testing
14611 Fenkell (5-Mile Rd.)
Detroit 27, Michigan
Res. Phone **VErmont 5-8724**

FOUNDRY CONSULTANT — NON-FERROUS Sand casting — permanent mold casting — centrifugal casting — in aluminum — brasses — bronzes — 80% leaded bronze — aircraft quality bearings and castings — **ED JENKINS, West Palm Beach, Florida — PHONE: Temple 2-8685.**

FOR SALE

MEASURE MOLDING SAND MOISTURE

Quickly & Efficiently With The Model 102 MOISTURE GAGE Direct Reading. Latest Electronic Design. Battery Operated. Highest Possible Sensitivity. Descriptive Literature FREE!

HENRY FRANCIS PARKS LABORATORY
(Established 1933)
7544 23rd., N.E.
Seattle 15, Washington

ALUMINUM FOUNDRY FOR SALE—once in a lifetime buy—8000 sq. ft. Building rents $250 per month. Business priced to sell—complete sand and permanent mold. Located Southeast. **Box G-105, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

WANTED TO BUY

BACK VOLUMES — Wanted to buy for cash of foundrymen, TRANSACTIONS American Foundrymen's Society and other scientific technical Journals. **Walter J. Johnson, Inc., 111 Fifth Avenue, New York 3, N. Y.**

own melting furnaces. Request reprint from MODERN CASTINGS. American Foundrymen's Society.
For Your Copy, Circle No. 106, Page 139

Produce your own CO_2 . . . reportedly at a fraction of purchased cost. Learn about this new system in a free brochure. Louis DeMarkus Corp.
For Your Copy, Circle No. 107, Page 139

Pyrometers . . . for precision temperature measurements described in catalog No. 175. Pyrometer Instrument Co.
For Your Copy, Circle No. 108, Page 139

Lift truck safety . . . is emphasized in safety kit available for the asking. Towmotor Corp.
For Your Copy, Circle No. 109, Page 139

Equipment leasing . . . releases working capital while at the same time availing your firm of the use of modern equipment. Read about this plan—request brochure. Acme Associates, Inc.
For Your Copy, Circle No. 110, Page 139

Vacuum Melting . . . of alloys. Film traces complete process, color, 16 mm, 17 min., free loan. Utica Drop Forge & Tool Corp.
For Your Copy, Circle No. 111, Page 139

Measuring moisture . . . is accomplished by weight or volume methods of determination. For a discussion of both methods, request technical report. Henry Francis Parks Laboratory.
For Your Copy, Circle No. 112, Page 139

Sigma phase . . . in austenitic stainless steels is subject of 8-page booklet covering nature and occurance, chemical composition, identification, etc. Electric Steel Foundry Co.
For Your Copy, Circle No. 113, Page 139

Tractor loader . . . catalog contains information on two transmissions available for the 83 hp unit, a bucket selection chart, and complete specifications. Allis-Chalmers.
For Your Copy, Circle No. 114, Page 139

Training Films

The following list of motion pictures and film strips will prove useful in educating your personnel to better perform their jobs. Circle the appropriate number on the Literature Request Card for complete information regarding these films. Items indicate whether films are available free of charge, by rental, or by purchase only.

Heat Treatment of Steel . . . shown in 16 mm, sound, black and white film; running time—22 min. Rental. United World Films, Inc.
For Your Copy, Circle No. 115, Page 139

New Supervisor . . . takes a look at his job. Stresses importance of human element. 16 mm, sound, 13 min. United World Films, Inc.
For Your Copy, Circle No. 116, Page 139

Straightening . . . malleable iron castings with air-operated drop stamp machine is subject of this film. Unit reportedly corrects distortion or warpage from annealing operation. Film is available free of charge. Chambersburg Engineering Co.
For Your Copy, Circle No. 117, Page 139

Free reprints

The following reprints of feature articles which appeared in MODERN CASTINGS are available to you free of charge. Use the Literature Request Card.

Green sand molding . . . advantages pointed out in reprint from MODERN CASTINGS. American Foundrymen's Society.
For Your Copy, Circle No. 118, Page 139

Steel castings . . . mechanical properties and processing techniques are both presented in technical reprint from AFS TRANSACT'ONS. American Foundrymen's Society.
For Your Copy, Circle No. 119, Page 139

Brass foundry . . . quality control is subject of 10-p reprint from AFS TRANSACTIONS. This article was the 1959 Edgar Hoyt Memorial Lecture. American Foundrymen's Society.
For Your Copy, Circle No. 120, Page 139

Metal cost . . . is evaluated for aluminum die casting in free reprint from AFS TRANSACTIONS. American Foundrymen's Society.

Malleable Founders Name Speitel

An improved technology and aggressive pioneering in new markets was called for by members of Malleable Founders Society at the annual meeting in Hamilton, Burmuda, June 6-7.

Incoming president Charles P. Speitel, Pennsylvania Malleable Iron Corp., Lancaster, Pa., said that the outlook for malleable was improving through new and varied uses.

Three new directors were named, one of the present directors was named vice-president. He is R. S. Bradshaw, Texas Foundries, Lufkin, Texas. Others are C. I. DeShong, Jr., Oriskany Malleable Iron Co., Oriskany, N. Y.; L. J. Gallagher, Ironton Div., Dayton Malleable Iron Co., Ironton, Ohio; and W. M. Dalton, Dalton Foundries, Warsaw, Ind.

Magnesium Group Met in England

At what was believed the first annual business meeting of an American industrial association ever held in Europe, the Magnesium Association, with headquarters in New York, in May elected new officers and directors. More than 40 members were in England for a joint one-week meeting with its British counterpart, the Magnesium Industry Council.

Charles A. Howe, Hills-McCanna Co., Chicago, was elected president. Other officers are: vice-presidents, E. H. Perkins, and J. E. Pepall, treasurer, R. D. Ferguson, executive secretary, Jerry Singleton.

The Editor's Report

by Jack Schaum

Round the World . . . is a new department appearing for the first time in our July MODERN CASTINGS. Foundrymen are becoming increasingly aware of the international scope of their industry. New technology, new competition, new markets are being born overseas. And we in this country must maintain an acute awareness of these new developments.

Don't be guilty of chauvinism—patriotism carried to the ridiculous. Too many Americans are deluding themselves and impeding industrial progress by the fiction that all the bright technological ideas of the world must originate in the United States. That just isn't so.

Just take a look at a few of the important metalcasting ideas spawned from the European fountainhead of technology in the past fifteen years: shell molds and cores, CO_2 process, water-cooled cupolas, air-set cores, boring injection, Shaw Process, Parlanti process, core shooters, and vacuum-stream degassing. True, once the idea is nucleated abroad, American foundrymen grab the idea and run with it—faster, further, and at a greater profit.

Learn this month in "Round the World" about direct reduction of iron ore—new revolution coming in iron and steel metalcasting. Keep yourself informed on a world-wide basis.

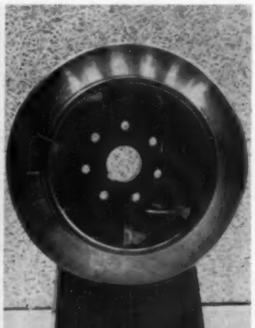
Tired waiting around . . . for that pot of molten aluminum to cool down to pouring temperature? Attach heavy iron chills to long handles and immerse them in the metal. Keep your eye on the thermocouple . . . you'll be down to temperature in a jiffy.

Plastic-shell process . . . is the name given to new investment casting technique developed by Precision Metalsmiths, Inc., Cleveland. This is the next step beyond the growing ceramic-shell process which uses wax patterns. Precision Metalsmiths has achieved a break-through with a new plastic pattern material which does not crack the ceramic shell when melted out. Conventional plastic pattern materials have too high a thermal expansion for use in the ceramic shell process; they are used in the old technique where patterns are invested in flasks with a backup material. Robert R. Miller, president of Precision Metalsmiths, states that the new plastic-shell process costs 40 per cent less than the older system and produces castings smoother than an egg shell!

Blow into fused silica backup . . . is a variation on an old theme which promises many of the advantages of hot metal patterns with the economy of wood patterns. Sand mix is blown between a contoured fused silica backup and a conventional wood pattern. Pattern is removed and mold cured in a dielectric oven. Fused silica backup is unaffected by induction currents. The backup is also sufficiently permeable to permit hot air curing of the mold, as well as venting of mold gases during pouring. The process uses inexpensive patterns, enjoys high speed production advantages of mold blowing, and produces close tolerance castings.

Design in Industry . . . was theme of exhibit in Gallery of Fine Arts, Columbus, Ohio. The art school selected machine-made products to demonstrate their qualities of form, beauty, and aesthetic values. Pictured here are two metalcastings displayed at the gallery to stimulate greater awareness of the beauty that surrounds us in everyday life. Below each is the name of foundry producing the casting. Looks like that oft heard expression "It's a beauty," is really quite appropriate when admiring one of those castings in your shop.

Railroad Coupler
Buckeye Steel Castings Co.



Pump Impeller
Bonney-Floyd Co.

Circle No. 153, Page 139